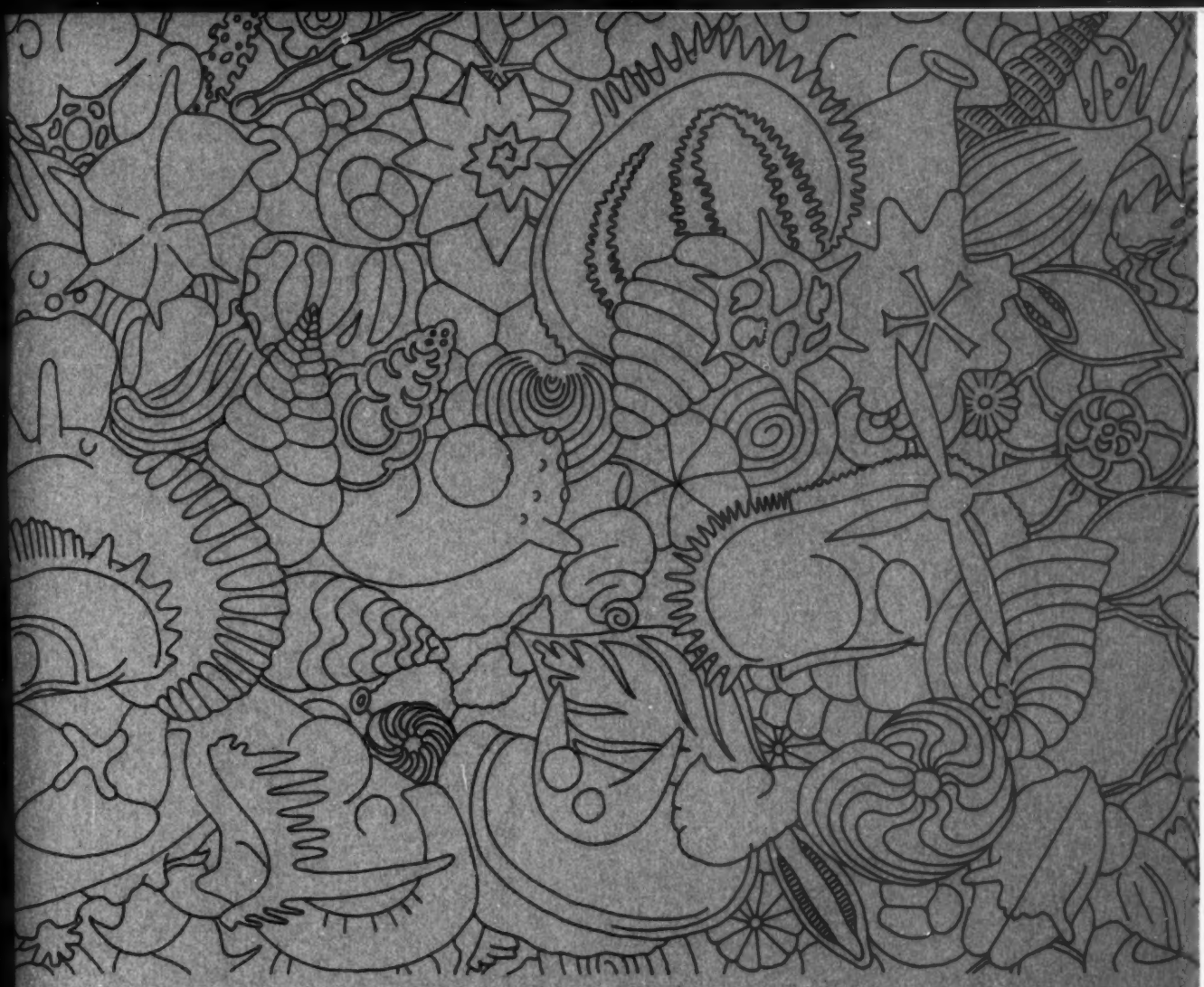

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ABSTRACT: *An account of the micropaleontology of the deep-sea sediments deposited in the various zones of the Tethyan geosynclines during the Jurassic and Cretaceous is presented. The study has been considerably hampered by lack of material. Most of the sediments studied came from the present western Mediterranean zone. In general, during the Jurassic (Tithonian) and Lower Cretaceous, radiolarians and globigerines predominated in the zones of subsidence, while* Nannoconus *and tintinnids were most abundant in the sediments of the deeper zones.* Pithonella *and* Globotruncana *predominate in Middle and Upper Cretaceous lithofacies.*

Jurassic-Cretaceous pelagic sediments of the western Mediterranean zone and the Atlantic area

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INTRODUCTION

In the course of the past few years I have obtained a large amount of lithologic material consisting of Mesozoic deep-sea sediments from the western Mediterranean area. Some of this material I have collected in the Balearic Islands and the northeastern part of the Sierras Beticas, and some has come to me through the kindness of geologists who have sent me samples from various localities. Thanks to their help, the present summary of the principal results obtained to date from the study of these rocks has been made possible. Because of the nature of the sediments and the vast area under consideration, these results are tentative, to be sure, and full of gaps and deficiencies as regards the continuity and distribution of these sediments in space and time. These gaps, however, will undoubtedly be filled by advances in the study of sedimentary lithofacies.

Thanks are due to the following persons for their valuable assistance: Professor R. Bataller of the University of Barcelona and Dr. A. Linares of the University of Granada, for Cretaceous material from the mountains of Almeria and of Granada, respectively; Dr. J. Cabanás, for a series of Cretaceous rocks from the zone of Larache (North Africa, Atlantic zone); Drs. A. Sousa Torres and J. M. Pires Soares of the University of Lisbon, for Upper Jurassic limestones from the Cape Verde Archipelago; Dr. R. Selli of Milan, for rocks from the Apennines; Professor P. Fallot of the Collège de France, to whom I am indebted for a large amount of material from the Sierras Beticas; Y. Jullien of Montpellier, for material from the Tithonian of Provence; and finally, Dr. G. Castany, director of the Geological Service of Tunis, and Dr. M. Durand-Delga of Algiers, for material from each of those regions.

I wish also to acknowledge the courtesy of those who have given me privately the preliminary results of their personal observations on certain groups of microorganisms discussed in this paper: Dr. F. Bonet's discovery of tintinnids in the Upper Jurassic of the Tampico region; Dr. P. Bronnimann's researches on *Nannoconus* and tintinnids in the Upper Jurassic and Lower Cretaceous limestones of Cuba; and Dr. A. G. Davies' discovery of numerous tintinnids in the Upper Jurassic of Iraq.

SCOPE

The microscopic study of the deep-sea, or essentially pelagic, sediments distributed throughout the extensive Alpine orthogeosyncline of the Tethys and its more immediate miogeosynclines (to follow Stille's terminology) has been generally neglected by lithologists. It is for this reason that I shall attempt to give here the first comprehensive view of the subject.

It has long been known, as is shown by more or less incidental and brief accounts in papers on Alpine geology, that a very fine-grained lithofacies composed of marly limestones or of siliceous beds (jasper, siliceous schists, etc.), filled with radiolarian tests, ap-

pears in many Middle and Upper Jurassic levels in the areas of the deep-sea sediments of the Alpine geosyncline. They have been studied in more detail in the Alps proper, and in the Carpathian zone. The existence of similar formations, extending to the western Mediterranean zone and also to the east, where they are connected by way of Turkey with the Iranian mountain ranges and the distant Himalayas, has been shown more recently. Because of the scanty amount of material published to date, however, these sediments are not well known, in spite of an interesting and varied composition revealing whole groups of organisms peculiar to these particular biotopes. The true nature of these sediments has been determined only comparatively recently.

Steinmann (1905) was one of the first to give special attention to the Radiolaria-bearing strata of the Alpine region, and he determined their abyssal character. This conclusion was of great paleogeographic importance and gave rise to much discussion at the time, as it was not generally accepted. At the other end of the Alpine zone proper, Kobayashi and Kimura (1944) have more recently contributed new data to our knowledge of the Paleozoic and Mesozoic Radiolaria-bearing deposits of Asia.

Neither the discussions of Steinmann's theory nor subsequent literature on the radiolarian strata has revealed their true microscopic composition and lithologic peculiarities. A description of the more important and extensive biofacies will therefore be given here:

Lithotopes widely extended in space and in time throughout the entire Alpine orthogeosyncline;

Reddish limestone lithotopes, replete with a globigerinid plankton that originated in the Dogger and later became predominant during certain portions of the Upper Jurassic;

Strata with dense swarms of a plankton of pelagic infusorians, the tintinnids *(=Calpionella)*, widely distributed at the end of the Jurassic and the beginning of the Lower Cretaceous;

Beds with microscopic algae (*Globochaete* Lombard and *Eothrix* Lombard), common chiefly during the Tithonian;

Strata with *Nannoconus* in the Neoeomian;

Levels with *"Oligostegina"* or *"Fissurina"* from the Albian to the Turonian;

Finally, the definite prevalence of marly limestone lithotopes with *Globigerina* and *Globotruncana*, until the end of the Cretaceous.

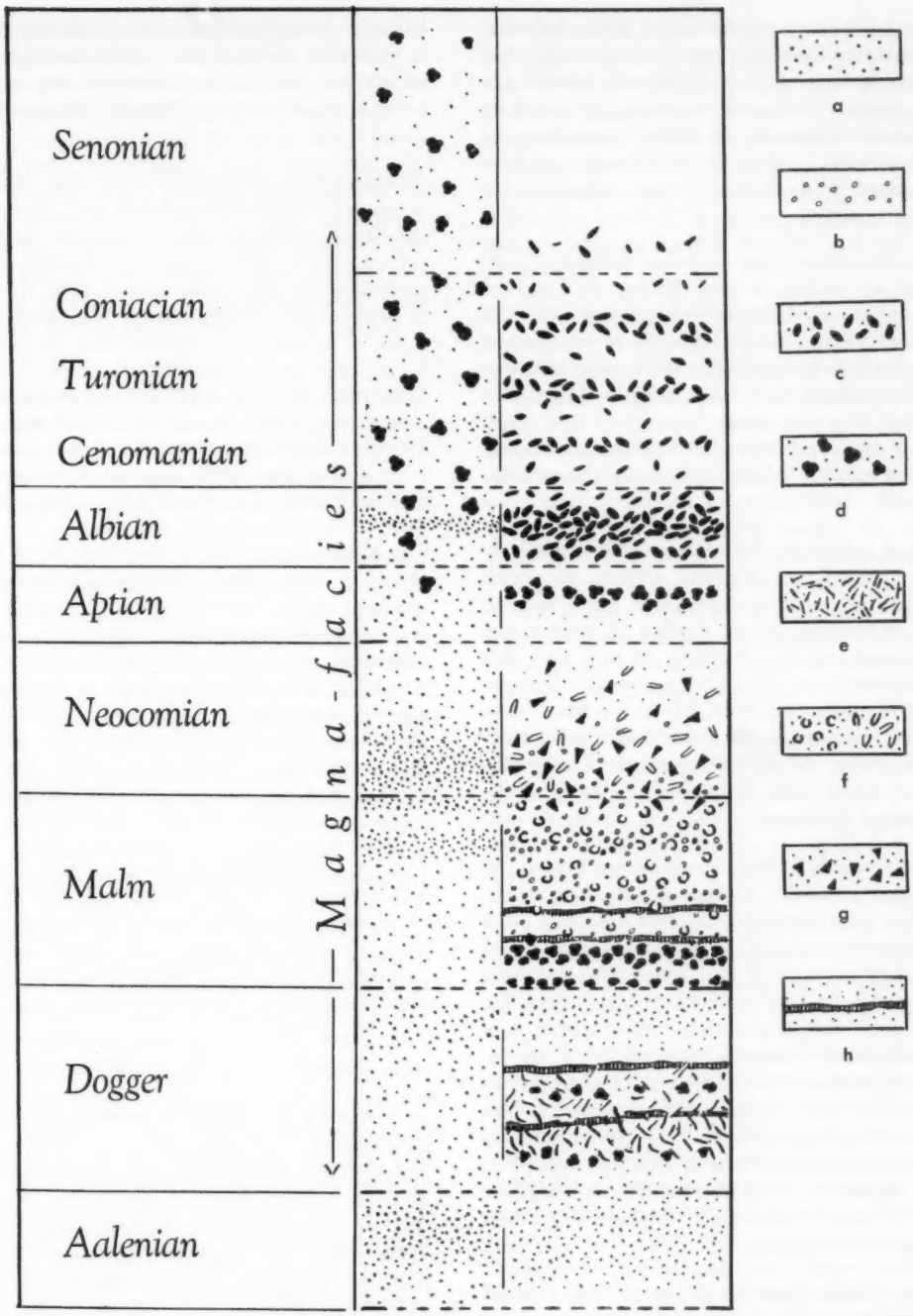
In the Balearic Islands and North Africa, radiolarian beds are found even in the Albian.

In a general way, the deep-sea geosyncline deposits of the western Mediterranean zone can be defined as a vast marly limestone lithotope, of great importance over a considerable period of time. This lithotope is characterized by the predominance of a wide magnafacies of Radiolaria from the Aalenian (upper Lias) to the Aptian-Albian. In its later part, from the Albian to the Maestrichtian, *Globigerina* and *Globotruncana* replace the Radiolaria. This is the most common, the most constant, and the prevailing sedimentation pattern throughout the great Alpine orthogeosyncline. In certain epochs and localities, different assemblages of peculiar micro-organisms, whose development was dependent upon both the time factor and special biotopes, either pelagic or benthonic, are intercalated in this magnafacies. A graphic summary of these general conclusions is given in the accompanying stratigraphic chart (text-fig. 1).

The thickness of these pelagic formations, with the exception of the strata containing *Globotruncana*, never exceeds a few meters. This was noted by Andrusov (1950) in the Carpathians. The monotonous series of marly limestones, lithographic in not a few instances, generally represents very fine-grained deep-sea sediments, pelagic in nature and lacking in terrigenous elements or with exceedingly rare and minute ones. The components of these deposits, which always occur in deep-sea areas, required immensities of time to form even very thin layers. In certain phases of the evolution of the geosynclines, they might be displaced and trangress over more or less neritic zones, forming beds of a mixed type that have no importance other than that of marking the passage from one class of sediment to the other.

RADIOLARIA

The first traces of Radiolaria-bearing pelagic formations of notable lithologic extent and importance in the Balearic Islands and the region of the Sierras Beticas in southern Spain appear in the upper Lias (Aalenian) (pl. 5, fig. 12). These lithotopes were formed, in large part, in the deep-sea area of the Betic-Balearic orthogeosyncline and etxended toward the southwest until they were lost in the Atlantic area south of the Paleozoic Iberian massif. This resulted in strata that became ever purer and thicker with the slow prevalence of deeper waters and a pelagic regime, during the course of this epoch.



TEXT-FIGURE 1

Stratigraphic chart of the general micropaleontological composition of the bathyal sediments of the western Mediterranean area. *a*, biotopes with Radiolaria; *b*, with *Globochaete*; *c*, with *Pithonella ovalis*; *d*, with *Globigerina* and *Globotruncana*; *e*, with fragments of *Halobia*; *f*, with tintinnids; *g*, with *Nannoconus*; *h*, intercalations of "Globigerinas" in the Dogger and Malm.

My present information on the extent of the Aalenian Radiolaria-bearing limestone beds is very scanty, but it is feasible to suppose that in deposits of this age and in analogous lithotopes, containing populations reduced almost exclusively to bathyal ammonites of the Mediterranean province, the microscopic composition is identical. In the Balearics these sediments are found finely stratified.

Under the microscope they reveal a cement of very finely granular calcite, a gray background against which the white radiolarian molds stand out. The latter are filled with minute crystals of transparent calcite, and the varied shapes of the former tests can still be distinguished, but always vaguely because of recrystallization of the calcite. However, from their constancy of shape and other details, there is no doubt that these are true Radiolaria, profoundly altered after deposition.

These typical radiolarian beds occur rather irregularly within the general stratification. Others, in which traces of radiolarian tests are more rare, alternate with them, and at times a certain rhythm of greater and lesser frequency can be observed. At any rate, this pelagic sedimentation continued uniformly throughout the entire upper Lias. It is only in the basal beds, and at their beginning, that the Radiolaria occur mixed with highly triturated fragments of echinoids and asterids, which tend to disappear rapidly in the higher strata of this series.

Aalenian facies with Radiolaria are known from other Mediterranean countries. In my opinion, the formations of this age represent the first elements of a pelagic sedimentation that predominated throughout the entire deep-sea zone of the Tethys. This sedimentation gave rise to very uniform strata, except for some that were transitional to neritic deposits containing terrigenous elements. No group of microorganisms other than the Radiolaria is observed in these deposits. The detrital elements present are always of very slight importance. This type of Aalenian Mediterranean sediment seems to have equivalents in the great thickness of Radiolaria-bearing deposits known as the Franciscan or Golden Gate series in the Coast Ranges of California.

During the Middle Jurassic (Dogger), the type of pelagic sediment described above was distributed over vast areas, at times along the borders of the orthogeosyncline, and at other times in its immediate vicinity or even in areas of obviously neritic influence. My data on its extent in the Sierras Beticas and Balearic regions is more complete. In the island of Majorca, for instance, the animal biocenoses that lived in its depths consisted of a rich assemblage of bathyal ammonites, *Phylloceras, Lytoceras,* etc., and extensive beds of a gregarious pelecypod, *Posidonomya alpina* Graas.

Sedimentation during this epoch was extremely monotonous, resulting in repeated gray marly limestone lithotopes, at times finely arenaceous because of the presence of a slight terrigenous fraction. These sediments suggest that from time to time the deposition of fine-grained pelagic muds was attended by an influx of continental material that consisted of uniformly fine-grained detrital elements. Many of the Betic zone deposits studied show strata with similar characteristics. In general, the Dogger sediments, over the Spanish area of the Alpine orthogeosyncline, reveal a greater influence of continental elements and a shallower depth than those of the Aalenian.

The microscopic study of thin sections of these rocks reveals a more varied composition than that of the Aalenian rocks. Parts of asterid and echinoid plates, fragments of foraminifera, ostracodes, and similar organisms are common in different localities. The cementing material in these rocks is also very uniform, since it is composed of granular calcite. The feature that characterizes these deposits in the Balearics and Sierras Beticas, as well as in other Mediterranean regions, and produces peculiar biotopes, is the enormous accumulation, in many beds, of long, thin, fine, arcuate fragments of a bivalve mollusk that J. de Lapparent (1923) identified as belonging to the genus *Halobia.* In my opinion, the shells of *Posidonomya alpina* have also contributed to the formation of these deposits. The concentration of these fine limestone rods becomes, at times, so great that they constitute the principal part of the rock. It has often been observed that wherever the remains of *Halobia* predominate, the Radiolaria tend to diminish (pl. 1, figs. 5-6).

Sediments with characters analogous to those just described exist in the south of France (Provence) and in North Africa. They are always associated with Dogger levels (Bajocian-Bathonian) and are frequently found at some distance from the deep-sea areas. Rocks that are very similar to these (to judge from his excellent photomicrographs) have recently been described from Aquitaine by J. Cuvillier (1951).

It is in precisely this kind of sediment, containing remains of *Halobia,* that the first traces of a globigerine fraction appear, although they are irregular and unimportant at first. The globigerine tests are not concentrated but are dispersed and isolated. In fact, it cannot

be affirmed that these are true globigerines, since all the tests are completely recrystallized and only a tenous silhouette is preserved, showing up white against the gray background of the rock because of the calcite granules replacing the walls and septa of the former test. Nevertheless, it is plain that the organisms in question are pelagic foraminifera of the *Globigerina* group (pl. 1, fig. 6). This globigerinic plankton of the Dogger is the earliest known within the area of pelagic sedimentation of the Alpine geosyncline, and was destined, in the regions studied, to acquire much greater importance toward the end of the Upper Jurassic.

In the Dogger a peculiar type of sedimentation occurred in the Sierras Beticas and Balearics region. The sediments are very fine-grained marly limestones, reddish or greenish in color, filled with nodules that are variable in size, with irregular, indistinct contours but analogous in every way to the matrix of the rock. These sediments have been called limestone "fausses-brèches" by French geologists. They were originally very fine-grained true muds that were impregnated by a great quantity of iron oxide of continental origin, giving rise to their present colors. These muds were shifted about by submarine currents or were affected by orogenic movements, which profoundly disturbed their bedding. The undissolved portions were redeposited within the same diluted muds, which again engulfed them, producing their pseudo-brecciated structure.

The "fausses-breches" are intercalated in the gray marly strata with Radiolaria, and in the Dogger they are not as important nor as thick as they are in the upper Malm. Thin sections show that they are radiolarian rocks with alternating layers of *Halobia* fragments, such as occur in the gray limestones already described.

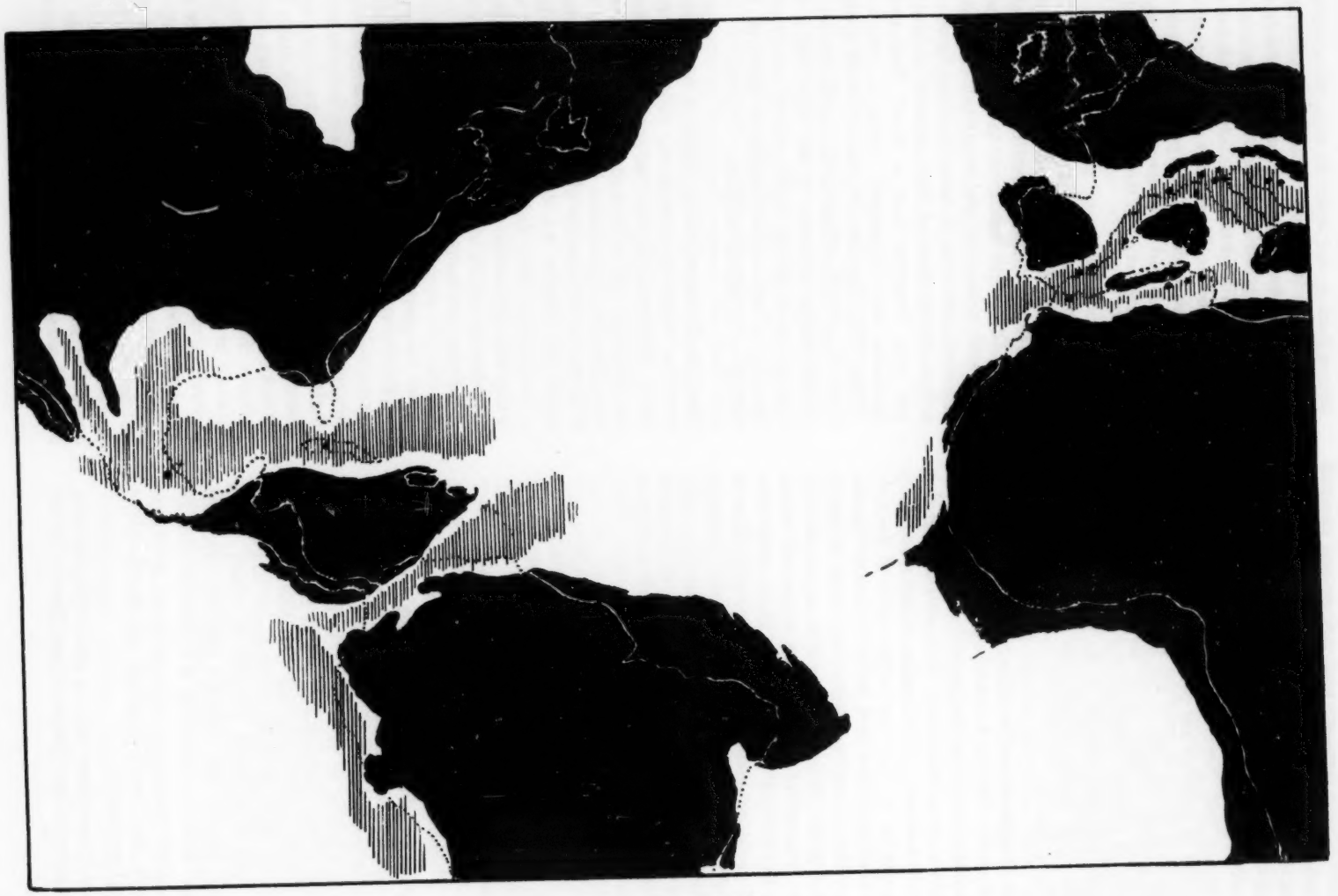
During the Malm (Upper Jurassic), the Alpine orthogeosyncline was more extensive in many regions. This was true in southern France, in the area of the Alpine chains, in Corsica, in Switzerland, in northern Italy, in a part of the Carpathians, and in the Caucasus. Limestones with Radiolaria and *Calpionella* were described from this last region by Andrusov and Koutek (1927) and Vassoevitch (1936). In North Africa (Morocco, Algeria and Tunisia), deep-sea sediments, or pelagic sediments deposited at a distance from the nearest continental mass, cover areas of great size and overlie gray marly limestones rich in populations of bathyal ammonites.

Wherever I have been able to study complete concordant series of the bathyal Upper Jurassic in the Sierras Beticas and Balearics area, the constancy of sedimentation from the Dogger to the Malm has been substantiated on the basis of the Radiolaria. In certain localities, the presence of slight terrigenous influences bears direct witness to the vicissitudes of the evolution of the geosyncline. There is no doubt that, at least in these Spanish regions, the Upper Jurassic, with the Tithonian, ushered in a long period of very pure pelagic sedimentation in the deep-sea area and along its margins.

The lithotopes containing Radiolaria appear here in a much more perfect state of preservation, and it is possible to recognize the tests of a great number of species. During this epoch very fine-grained limestone, filled wtih radiolarians and remains of *Aptychus*, was deposited over what is now the Cape Verde Archipelago. In the island of Maio, a series of hard, compact gray limestone beds is found. They are now dislocated and fragmented owing to eruptive intrusions. The discovery of sediments with Radiolaria in the Cape Verde Island group verifies the extension of the pelagic sediments of the upper Malm of the Tethys regions through to the Atlantic area, including some as yet little-known deposits of this type in the Riff chain of Spanish Morocco.

The gray limestones of the island of Maio generally carry an enormous quantity of radiolarian remains (pl. 1, fig. 2; pl. 3, fig. 32), but in some beds they are less abundant. All, without exception, contain isolated rhombohedrons of dolomite. It is difficult to determine, from the small quantity of material I have had to work with, whether this dolomite was formed in situ or was derived from distant coralline formations. It is now known from the studies of Weynschenk (1951) that rhombohedrons of dolomite are present in many of the deep-sea formations of existing seas.

Under the microscope, the radiolarian limestones of the Mediterranean zone reveal a very finely granular calcite at times impregnated with chalky impurities. Frequently it is possible to observe between crossed nicols, in the thinnest portions of the slides, a considerable number of diminutive coccolith disks. They show a black cross with polarized light. Their numbers indicate that they, too, have contributed in large measure to the formation of these strata. In these limestones, the radiolarian molds are in a better state of preservation, and their spines, varied shapes, etc., can be readily distinguished. The epigenizing agent of the Radiolaria is not always calcite, however. Sometimes, although the rock may be completely calcareous, a slight siliceous impregnation shows that they are preserved in a stable form of silica, chal-



TEXT-FIGURE 2

Paleogeography of the Upper Jurassic, with the distribution of tintinnids in the bathyal areas indicated by black dots.

COLOM

TEXT-FIGURE 3

Paleogeography of the Albian—Cenomanian, with the distribution of *Pithonella ovalis* indicated by black dots.

cedony. At other times, but less frequently, calcium phosphate fills the interior of the tests. Intercalations of siliceous nodules are common.

In the Sierras Beticas and Balearics regions, beds of fine-grained limestone filled with *Globigerina*, similar to those described from the Dogger but lacking in *Halobia* remains, reappear in the lower Tithonian. They are of greater importance here, many of the beds reaching a thickness of one meter (pl. 5, fig. 13). The ammonites present in these deposits (*Perisphinctes*, etc.) are characteristic of deep seas. Formations that I have been able to examine personally, and the study of material from other localities, show that this globigerinic flood was not repeated in the middle nor in the upper Tithonian, nor during the Lower Cretaceous (Neocomian). It was, therefore, rather brief and inconstant. So far, I have found it only in the regions mentioned, but it may possibly appear in other countries of the Alpine zone and in North Africa. I know of no bibliographic reference to it. The limitation of these biotopes with *Globigerina* to the base of the Tithonian is a curious thing, in view of the fact that the depth and the pelagic conditions of sedimentation persisted throughout this and the following epochs.

TINTINNIDS

The first representatives of the tintinnids, loricated infusorians of the order Oligotricha, appear in the Tithonian strata. These peculiar free-swimming pelagic forms are common in today's seas. These delicate micro-organisms were widely distributed in the warm waters of the Tethys during the Tithonian and Neocomian. Dense swarms of their populations deposited their loricas in fine-grained pelagic muds, which have preserved them until modern times. Reported only from the Alpine region (Switzerland) at the beginning of the century, they are now known to cover vast areas (text-fig. 2). Recent studies show their widespread occurrence over the geosyncline area, from the Tampico region of Mexico (F. Bonet), and from Cuba (P. Bronnimann), to Iraq (A. G. Davies).

The actual time of their appearance is not known, but it is possible that they are pre-Triassic. There are no positive data, however, to prove this. At certain times during the Tithonian, and chiefly in the upper Tithonian, two small, oval or almost spheroid species, *Calpionella alpina* Lorenz and *C. elliptica* Cadisch, predominate. The former is the first species known, having been described from the upper Malm of Switzerland in 1901.

Occasionally, and always in lesser numbers, their dense populations include *Calpionella undelloides* Colom, *C. massutiniana* Colom, and *Tintinopsella oblonga* Cadisch, the last species especially in the higher levels, or at the base of the Berriasian. Populations of *C. alpina* and *C. elliptica* are known from the Caucasus, the Carpathians, the Swiss and Italian Alps, the Apennines (Monte Nerone), France (Provence), Spanish Morocco (M. Blumenthal), Algeria (G. Castany), Tunis (M. Durand-Delga), and the Sierras Beticas (R. Bataller, A. Linares). So far, both species appear to be exclusively Tithonian, extending at most to the base of the Berriasian, as shown by Jullien's slides from Ceyrac-Sauve (Provence).

This assemblage was gradually replaced by other groups during the Berriasian. At that time, *Tintinopsella carpathica* (Murgeanu and Filipescu), a species that existed until the beginning of the Barremian, began to dominate, at least in the Balearics. However, from the Berriasian on, there appeared a larger number of tintinnid forms belonging to different genera, e.g., *Calpionellopsis, Calpionellites, Stenosemellopsis, Favelloides, Tintinopsella, Amphorellina, Rhabdonelloides, Salpingellina, Coxliellina*, etc. A great variety of tintinnids is present in the Lower Cretaceous, although some of the species are not common.

I consider the distribution table of species that was given in my paper of 1948 still valid, at least as far as the Spanish regions are concerned. Recently undertaken studies will provide more precise knowledge of their vertical distribution over wide areas of the ancient Tethys, and will probably modify the regional (Mediterranean zone) character of this table.

Tintinopsella carpathica (Murgeanu and Filipescu) is the most common and predominant form in many of the tintinnid swarms in Lower Cretaceous levels (Valanginian-Hauterivian). It is almost always accompanied by species of other genera. For instance, in the Valanginian of the Balearic Islands and southern Spain it is usually associated with *Calpionellites darderi* Colom. In Algeria and Tunis, from the Berriasian on, there is a striking abundance of a tintinnid plankton composed almost exclusively of *Tintinopsella longa* Colom and *Stenosemellopsis hispanica* Colom. In this assemblage the occurrence of *T. carpathica*, represented by somewhat larger specimens than in the Sierras Beticas and Balearics regions, is notable.

The Lower Cretaceous tintinnid plankton of North Africa reveals a greater vitality and a slight difference in composition, when compared with its equivalents

from the more northern part of the Tethys. In Algeria and Tunis, it is not rare to find biotopes with fossil tintinnids occurring in lithotopes in which calcified sponge spicules and remains of benthonic foraminifera abound, while Radiolaria, on the contrary, are scarce. These deposits, neritic in great part but without gross detrital elements, are entirely analogous to those of the northeastern region of Majorca (Arta and Capdepera). During this epoch, the northeastern region of Majorca was under the direct influence of the emerged Tyrrhenian massif, which included in its western part the Paleozoic area of the island of Minorca. This massif, by its proximity, directly influenced the composition of the animal biocenosis that inhabited the coasts of Minorca, as well as the neritic character of the sedimentation of the northeastern part of Majorca. The deep-sea zone of Majorca, toward the southwest, remained out of reach of this influence.

ALGAE

Other micro-organisms that occur in the fine Tithonian Mediterranean sediments with Radiolaria are the algae described in 1938 by Lombard under the name of "organisme D." He described them again in 1945 in more detail and gave an interpretation of their structure and taxonomic position. Lombard considered them to be two distinct forms, *Globochaete alpina* Lombard, belonging to the Protococcaceae, and *Eothrix alpina* Lombard, belonging to the Ulothricaleae.

Globochaete alpina first appears in the highest levels of the Malm. I have seen it in Jullien's slides from the Kimmeridgian of Sainte Croix de Quintillargues et Vauvage, Provence, which contain good, easily recognizable specimens. Both algae are widely dispersed geographically; *Gl. alpina* has been recognized by Vogler in the Upper Jurassic of Misoöl, Indonesia, and is common throughout the entire Alpine zone of the Tethys. I do not know whether or not it has been found in deposits of that age in Central America.

Lombard says in his notes that he found *Globochaete* and *Eothrix* in Malm strata of various Alpine structural units, such as those belonging to the autochthonous series, the Helvetian decken, and the ultra-Helvetian and pre-Alpine decken of Switzerland and Haute-Savoie. For my part, I can say that the two forms are common in the Andalusian and Balearic Tithonian, in Provence, at Monte Nerone (Apennines), and also in North Africa.

In thin section, under low magnification, lithotopes rich in *Globochaete* and *Eothrix* reveal an intricate and chaotic mixture of different organisms, most of which are difficult to interpret (pl. 1, fig. 1; pl. 5, fig. 1). At higher magnifications, the zoospores of *Globochaete alpina* can be distinguished, and their stages of division can also be recognized. The latter are generally the most numerous (pl. 5, fig. 1), and are very widely disseminated. The minute bilobate or quadripartite spheres (pl. 2, figs. 1-4; pl. 3, figs. 1-27) show a black cross between crossed nicols.

Gl. alpina is easier to identify than its companion *Eothrix*, as it offers a series of more typical and constant characters. The most common specimens are zoospores in the process of dividing (pl. 4, figs. 6, 8-11, 18), which are always found isolated and disseminated in the strata that contain them in abundance. A magnification of 300 to 500 times is necessary for their detailed study. Many of the zoospores representing young stages appear as epiphytic forms attached to any submarine object within reach (pl. 2, figs. 1, 2). Mature stages, represented by forms that are larger in size and flattened or urn-shaped, are attached to supports of various kinds (pl. 2, figs. 3-4; pl. 3, figs. 2-4, 10).

On the other hand, the forms of *Eothrix* are more varied and less constant, and at times so questionable as not to be admitted by some students. However, one finds sections that correspond perfectly to Lombard's description of *E. alpina* side by side with specimens of doubtful classification that may perhaps be parts of other organisms belonging to groups higher in the zoological scale, such as claws of pelagic crustaceans, asterid remains, etc. For example, there are linear or chain-like forms, as in pl. 4, fig. 3, consisting of a long line of cells with a larger cellule sometimes situated approximately in the center of the chain. Lombard considers these to be sporangia. Sections of the thalli of *Eothrix* are also interesting because of their easily recognizable "Y" shape. The arms are thick and blunt (pl. 3, fig. 28; pl. 4, fig. 3), or sometimes thinner, or again somewhat irregular (pl. 4, figs. 12-13). Consequently, they are more likely to have belonged to other organisms. The varied shapes that the thalli at times adopt may render them unrecognizable and produce beds of chaotic appearance. At times, these beds with *Eothrix* and *Globochaete* contain populations of *Calpionella alpina* and *C. elliptica* in equal abundance. This produces a peculiar organic type of sediment very typical of the Mediterranean Tithonian beds.

Lombard attributes the great abundance of thalli and zoospores of both of these algae to the presence of a true "sargasso" mass at the surface of the seas of that time, similar to the modern planktonic marine assemblages of tropical seas. Although the distribution in

time of *Gl. alpina* was great, the beds in which this form is typically found associated with *Eothrix* as described above (and figured in pl. 5, fig. 1) are confined to the Tithonian, if it is permissible to generalize from the data gathered so far. This would seem to show that, at least during the Tithonian, both algae formed part of a rich and varied assemblage of pelagic organisms that spread over broad marine areas throughout the deep-sea and neritic zones of the Tethyan geosyncline. A comparison with a "sargasso" mass is feasible, although at present we can form only a very poor idea of its composition.

With the arrival of the Neocomian (Lower Cretaceous), pelagic sedimentation, judging from the presence of Radiolaria and tintinnids, continued without any notable change, although different populations of species succeeded one another in the composition of the planktonic masses. The preponderance of Lombard's algae diminished rapidly, the disappearance of *Eothrix* being more marked. In the Valanginian deposits it is very rare and in some cases totally lacking.

NANNOCONUS

In the transition beds between the Berriasian and Neocomian, a new group of diminutive and as yet enigmatic micro-organisms, *Nannoconus,* appears. In spite of its minute size, it is often present in such great numbers that at times it forms very pure limestone lithotopes with its countless tests (pl. 4, fig. 1; pl. 5, fig. 9). Biotopes with *Nannoconus,* first known from de Lapparent's studies of material from Provence (Berrias) and the island of Majorca and from Kamptner's studies of the Biancone limestone of the Alps, are always found associated with bathyal limestone lithotopes with Radiolaria. At first they were considered simply a micropaleontological curiosity of slight lithologic value. Later studies have shown, however, that they represent an important sedimentary element within the framework of the bathyal deposits of the Tethys, for they have given origin to marl and limestone strata composed almost entirely of their remains. I believe that the *Nannoconus* beds represent the deposits most closely associated with the bathyal areas of the Alpine geosynclines. Although it is true that in certain localities they show stages of transition to other sediments of a more neritic type, it is nevertheless certain that these tiny organisms tended to disappear rapidly as soon as any regular or persistent neritic influence was felt.

Throughout the seas of the Tethys during the Neocomian, *Nannoconus* biotopes represent the sediments of greatest depth within the great subsident series in the marine trough. A plankton of Radiolaria and tintinnids was also deposited with them. The *Nannoconus* beds carry a rich assemblage of smooth ammonites, typical of the deep-sea areas of those times.

Sediments with *Nannoconus* are now known to be widespread. They have been cited from Rumania, the Alps, the Apennines (Biancone limestone and Neocomian majolica), Provence, the Balearic Islands, the Sierras Beticas, North Africa (Algeria and Tunisia), the Antilles (Cuba, P. Bronnimann), and Mexico (Tampico, F. Bonet), thus proving their widespread distribution throughout the immense areas of the Tethyan geosynclines. It has been found that they are always associated with a pelagic facies containing Radiolaria and tintinnids. Bronnimann (1954) believes that Kamptner's form, *Nannoconus steinmanni,* is distinct from that described by de Lapparent as *N. colomi,* and he also indicates the existence of various other types of *Nannoconus* in his material from Cuba. He points out, however, that "the stratigraphic distribution of *Calpionella* and that of *Nannoconus* appear to be the same in Cuba as in southern Europe."

Nannoconus sediments are important throughout the Sierras Beticas and Balearics, and consist of very pure, fine-grained, sublithographic limestones alternating with beds of a more marly nature. The strata are not very thick, however, because of the tiny size of their components, but the deposits indicate that a considerable time interval must have been required for their deposition. Neocomian beds containing *Nannoconus* have recently been found in Algeria and Tunis (Colom, Castany and Durand-Delga, 1954). Data on the extent and importance of these sediments are incomplete, but may possibly be supplemented in the near future.

The true taxonomic affiliation of *Nannoconus* is as yet unknown. Its elongate test, tapering toward the opening and made up of radial calcite lamellae, has a very reduced internal cavity. One's first impression, on examining its countless sections, is that it represents some flagellated free-swimming planktonic marine form whose living representatives are still poorly known. Its delicate test attains a length of 25μ to 30μ. The possibility that it is a flagellate phase belonging to the life cycle of some unknown form must also be admitted, although we have no positive data in favor of this supposition. Deflandre (1952), an assiduous worker on living and fossil Protozoa, considers it to be a probable but not yet proven member of the large group of coccolithophorid algae. There is nothing to prove that *Nannoconus* was a pelagic and not a ben-

thonic organism. Its occurrence in large masses makes the first interpretation seem the more acceptable. Its association with a true plankton population (Radiolaria, tintinnids) also favors this view. However, there is nothing positive in all this.

Up to the present time, I have found no traces of a globigerine facies in the entire bathyal Neocomian of the Sierras Beticas and Balearics. Nevertheless, it is difficult to believe that a plankton of this nature was not deposited, especially when we know that a similar one existed during a part of the Tithonian. The Neocomian *Nannoconus* beds show strong alteration of their components, the Radiolaria and tintinnids being epigenized by calcite, and in certain strata the former are epigenized also by hematite. The absence of tests of *Globigerina* or related pelagic forms from these strata might be attributed to their having been destroyed by diagenesis during consolidation of the deposits. On the other land, their disappearance may have been a result of their depth of deposition, as happens in the bathyal or abyssal zones of present-day seas. This is still an obscure question, and I have little data on it.

In the Balearic Islands, during the Aptian and Albian, a slow process of emergence began, giving rise to argillaceous beds containing terrigenous components. They do not contain *Nannoconus* but do contain an abundant *Globigerina* plankton, in which *Globigerina subcretacea* Glaessner is present.

During the Albian, some evidence of pelagic sediments with Radiolaria is found in the Betic-Balearic zone. This is also true in the region of Larache, in the Atlantic zone of Spanish Morocco. The latter sediments are very pure and are peculiar in that all the radiolarian tests are replaced by hematite. *Nannoconus* is also absent from these Aptian-Albian beds; it seems to have disappeared entirely by the end of the Barremian, at least in the western Mediterranean zone. The Albian strata, rich in Radiolaria, are homologous with those described recently from North Africa by the French geologists Magné and Sigal (1954). Possibly their wide extension in North Africa is related to the deposits of similar nature that exist in the Antillean region, the most precise description of which we owe to the late Dorothy K. Palmer (1934). In Cuba, there exist very rich radiolarian deposits that contain fragments of *Aptychus* in some localities. Some of these deposits appear to be Middle Cretaceous, but others extend up to the base of the Lower Eocene. There exists, then, a notable coincidence of radiolarian formations over great distances in the two present slopes of the Atlantic, revealing a possible mutual relationship in the ancient area of the Tethys.

"OLIGOSTEGINA" AND "FISSURINA"

In the upper Aptian beds, but principally in the Albian, there appear in the pelagic zones of the Alpine geosyncline the first biotopes containing *"Oligostegina"* or *"Fissurina,"* micro-organisms of unknown nature (incertae sedis). These are very widespread in the marly limestone lithotopes and continue into the Turonian and lower Senonian, where they tend to disappear. The peak of their greatest predominance seems to correspond with the Albian, at least in the extensive Betic-Balearic zone, in North Africa, and in many countries of the Alpine arch. This does not imply, however, that they may not also be common elsewhere at higher levels that are considered Cenomanian or Turonian by various authors.

"Oligostegina" is generally very abundant and is the principal rock-forming element in many cases (pl. 3, fig. 31; pl. 5, fig. 2); in others it is less frequent, and only isolated, irregularly scattered specimens are found in the slides. In the latter case, some investigators have recently supposed their tiny tests to be fragments of the older groups of *Calpionella,* such as *C. alpina* and *C. elliptica,* which are typical of the Tithonian. Careful examination, however, shows that the resemblance is merely superficial. Unlike *Calpionella, "Oligostegina"* has a strong calcareous test with thick walls and a rather narrow apical opening. Its oval outline always has the same silhouette if one takes into account the variations of orientation that random sectioning produces, confirming that it is one and the same organism.

"Oligostegina" and *"Fissurina"* were first described in 1865 from the Swiss Alps by Kaufmann, as *Oligostegina laevigata* and *Lagena ovalis.* After Kaufmann, these forms were reported from the Alps, the Carpathians, and other localities, principally from Albian levels. No particular attention was given to their structure and taxonomy, since the authors were chiefly interested in defining the various lithologic facies observed. These species proved to be extremely constant and characteristic for one of these facies throughout the Alpine zone. In addition, *"Oligostegina"* seems to have been very abundant east of the Alpine region proper. I have recently examined some fine gray Albian limestones collected by Nagappa near Digboi, Assam (India), which are rich in the tests of *"Lagena ovalis."* This is the first evidence of their presence in the region of the Asiatic Tethys, and we may assume that further investigations will reveal their widespread presence there. *"Oligostegina"* has also been reported from the Chalk of Russia and from the Cenomanian, Turonian, and Senonian of the Caucasian chain.

Sujkowski (1930) described Turonian deposits with abundant *"Fissurina"* from the Polish Carpathians. *"Lagena ovalis"* is also known from a fairly large number of deposits in the Alpine arch, i.e., the French, Swiss and Bavarian Alps. It is also very common in the Albian of the island of Majorca and the Sierras Beticas. It is less common in the western Pyrenees region, and occurs only in the Senonian. It has been found recently (Colom, Castany and Durand-Delga, 1954) in Algeria and Tunisia in beds of Albian age. Although it is common in these beds, it never occurs in great masses. Further studies, however, may possibly reveal with greater exactness its distribution and occurrence there.

Spherical bodies similar to Kaufmann's species have been reported from the Albian of Mexico, the Coniacian San Felipe limestone (Mexico), and from Texas. Its distribution in time, therefore, ranges from the upper Aptian to the lower part of the Senonian. Its presence is not always linked with deep-sea or essentially pelagic formations; it also invades biotopes that are largely neritic although free from gross detrital elements. Nevertheless, *"Lagena ovalis"* seems to be principally characteristic of pelagic biotopes of the great subsident areas of the Tethys during the Middle Cretaceous and the early part of the Upper Cretaceous (text-fig. 3).

After a careful study of Wanner's paper (1940) on calcareous spheres resembling *"Oligostegina,"* I believe it can be affirmed that the micro-organisms described by him have no connection with Kaufmann's forms. Although they resemble them in their general spheroid shape, the tests differ in structure. Wanner's forms, moreover, are from the Upper Jurassic.

"Oligostegina" is very abundant in the deposits of Majorca, and I have examined its structure carefully in the hope of ascertaining its taxonomic affiliation, although I have never been able to obtain well preserved isolated specimens. The hard, fine-grained, compact limestone in which they are embedded cannot be dissolved to free them, so that their study has necessarily had to be from thin sections. What, then, are these organisms — unilocular foraminifera, or representatives of other protistan groups?

An examination at high magnification of the multitudinous tests contained in the slides shows that they are composed of two calcareous layers, a fine, thin external one and a thick inner one. I have never been able to see, with a polarizing microscope, any arrangement of radial lamellae such as many calcareous foraminiferal tests show. The orientation of their calcite fibers is in a direction longitudinal to the test. I have also examined the interior of the test in better-preserved specimens in an attempt to find a calcareous tube extending from the aperture into the interior of the test, such as those present in many species of true *Entosolenia*. However, I have been unable to see any such structure, as the interior of most of the tests is filled with a mass of recrystallized calcium carbonate that has destroyed all traces of any internal structure (pl. 5, figs. 3-8, 10). Other tests are filled with a marly sediment, in which no evidence of the possible existence of an internal hyaline tube is preserved.

The *"Lagena ovalis"* material that I have worked with has shed little light on the question of its taxonomic position. I have found no positive indication of a structural feature revealing any systematic affinity with the foraminifera or any other group. The only possibility left is a more or less well-founded hypothesis that *"Lagena ovalis"* belongs to the group of the true Entosolenias. These forms generally have minute simple tests with a rather robust calcareous wall, and a single internal cavity with an internal hyaline tube. If, in time, this affinity were proved, *"Lagena ovalis"* would then have to be considered a benthonic rather than a planktonic micro-organism. It would have lived in neritic biotopes bordering the bathyal zone or possibly within the zone itself. Its enormus accumulation in certain beds of marly limestone lithotopes would be in great part a result of transportation by bottom currents, by which it was deposited irregularly in fine-grained lime muds far removed from detrital influences. A comparison with organisms other than the foraminifera has also failed to throw light on its possible origin and systematic position. For the moment, and in the present state of our knowledge of these forms, I consider Kaufmann's *"Lagena ovalis"* a foraminiferan closely related to *Entosolenia*.

With regard to the names by which Kaufmann's two diminutive species should be designated, it must be agreed with Glaessner (1945) that most of the various designations used for them cannot be maintained. Kaufmann actually established his monotypic genus *Oligostegina* for the form *O. laevigata* (in: Heer, 1865, *Die Urwelt der Schweiz*, p. 107, fig. 108; Upper Cretaceous of Switzerland). To judge from the original figures, this is an enigmatic micro-organism, incertae sedis, consisting of a calcareous test formed by the union of spheroid chambers in groups of two or three. These chambers give the impression of belonging to the early portion of minute Globigerinas or Globotruncanas, which are also present in these same sediments. On the other hand, Kaufmann's other species, *"Lagena ovalis,"* also called *Pithonella ovalis* (Kaufmann) by Lorenz (1902, Naturf. Ges. Freiburg, Ber., vol. 12, p. 13, pl. 9, fig. 2; monotype: *Lagena ovalis*

TEXT-FIGURE 4

Pithonella ovalis (Kaufmann). Albian; Majorca. × 400.

Kaufmann, 1865; Upper Cretaceous of Switzerland), is the species that characterizes the rocks called *"Fissurina"* or *"Oligostegina"* limestones by modern authors.

Kaufmann's two forms appear to be two very different things. *Oligostegina laevigata* may possibly be no more than a fragment of the proloculum of a *Globigerina*, as can be seen in any typical thin section of these marly limestone lithotopes. *"Lagena ovalis"* is an unknown micro-organism, well characterized by its constant and well-defined shape, having an oval calcareous test with a single opening. Evidently the latter species cannot be included in the genus *Oligostegina*, as its characters do not correspond to those of Kaufmann's monotypic form *O. laevigata*. For this reason I propose to redescribe the genus *Pithonella* as follows:

Genus **Pithonella** Lorenz, 1902

Genotype: Lagena ovalis Kaufmann, 1865 (monotypic).

Characters: Test minute, about 70 mm. in length and 40 mm. to 50 mm. in diameter, unilocular, oval in outline, circular in section, with a rather narrow opening at one of its extremities. The test is calcareous and possibly was so originally, and is composed of two calcareous layers, a thin external one and an internal one with walls thick in relation to the size of the test, composed of fibrous calcite oriented longitudinally to the axis of the test. In its present state of preservation it reveals under the microscope no perforations (pores) other than that of the main aperture (text-fig. 4).

As I have said above, *Pithonella ovalis* (Kaufmann) is probably a member of the Buliminidae, and very close to the living genus *Entosolenia*, a mere hypothesis that in time may be confirmed or disproved. The present chaotic state of our knowledge concerning the structure and systematic position of many species of *Lagena* and *Entosolenia* does not facilitate the solution of this problem.

Geologic distribution: Middle Cretaceous and lower part of the Upper Cretaceous.

GLOBIGERINIDS

Biotopes with *P. ovalis* alternate in many localities with others containing Globigerinas and Globotruncanas. The latter are enormously widespread, for although the two genera represent a well-defined pelagic element, their abundance in the plankton of the Middle and Upper Cretaceous was so great that their remains invaded zones of highly varied sedimentation, ranging from purely pelagic and possibly bathyal zones to others whose neritic or even littoral character is evident. A precise knowledge of the distribution, in space and in time, of the biotopes with Globigerinas and Globotruncanas, whose numerous species so well define the age of their marly limestone sequences, would be extremely interesting. This would be especially true if it were possible to study the species in their different stages of development, not only from a micropaleontological point of view, as is generally done, but preferably from a purely sedimentary one, with its multiple contacts with, and variations from, other sedimentary units within this modality. The sediments with Globigerinas and Globotruncanas, however, tend to differ greatly from the fine-grained deep-sea sediments examined so far. They appear to represent pelagic sediments in most cases, but may also represent sediments proper to the continental platform, since they correspond, to a considerable degree, to a time of wide expansion of the Upper Cretaceous seas in the entire Mediterranean zone. To judge from the extensive literature on facies with *Globotruncana*, its distribution undoubtedly embraces widespread areas principally following an equatorial line more or less connected with that of the seas of the ancient Tethys.

CONCLUSIONS

The study of the deep-sea sediments corresponding to the great Mediterranean orthogeosyncline of the Tethys reveals a unity of sedimentation and a uniformity of its lithological character over many countries. The writer wishes to state, however, that he does not consider every sediment containing Radiolaria as representing deep-sea deposits. That would be an exaggeration of known facts and a return to narrow, discarded interpretations. But when, in certain localities, a sediment composed of Radiolaria, either alone

or accompanied by tintinnids, *Globochaete*, etc., predominates, and when its strata are free from coarse terrigenous elements, then I believe that such beds represent times of maximum depth for those areas. At times, however, the planktonic contribution was so great that it easily transgressed over the surrounding areas of neritic sediments. In deposits of this nature, delicate pelagic organisms were also preserved if the detrital content did not prevent their fossilization. Consequently, all degrees of composition between very pure pelagic sediments and those characteristic of coastal neritic deposits exist throughout the Mediterranean geosynclinal trough. The great majority of the examples mentioned here belong, in my opinion, to the borders of the geosynclinal troughs, rather than to their truly bathyal regions. I believe that true abyssal formations are extremely rare in the entire Mediterranean zone or, more properly speaking, are beyond the reach of our means of investigation. The Radiolaria-bearing siliceous schists and jaspers associated with green eruptive rocks in the Alps and other regions of the eastern Mediterranean may represent true deep-sea sediments characteristic of the abyssal area.

In the material examined from the western Mediterranean zone, I consider the lithotopes with *Nannoconus* to be the formations of deepest origin. In the Balearic area and in the Sierras Beticas, areas that I have studied personally and with great interest for many years, the fine *Nannoconus*-bearing limestone strata, whose unique faunal element is a monotonous series of smooth bathyal ammonites, always represent the time of maximum depth in the bathymetric evolution of the extensive Alpine orthogeosyncline and its immediate dependencies. The same thing must have occurred in the Neocomian majolica and Biancone limestones of the Swiss and Italian Alps. These very fine sediments, composed of an enormous mass of tests of *Nannoconus*, tintinnids and Radiolaria, with only an insignificant terrigenous contribution or none at all, must have been formed far from all continental influence.

The problems that the deep-sea sediments of the Tethys suggest to geologists and lithologists are multiple and interesting. With the advance of lithologic studies, the mystery now enveloping them will slowly be dissipated, and a better understanding of this peculiar class of sediments, composed principally of four great groups of micro-organisms — Radiolaria, tintinnids, *Globochaete* and *Nannoconus* — will result. The present paper represents no more than an outline of the earliest stages of our knowledge, and does not pretend to offer any definite conclusions. That would be premature and ineffective. Only concerted work by the geologists and lithologists of the Mediterranean countries, where the deep-sea sediments of the ancient Tethys predominate, can help to resolve satisfactorily the question of the intimate composition of the bathyal or abyssal deposits of the Alpine geosyncline area, and so reveal the true nature, value, and extent of its Mesozoic deep-sea deposits.

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EXPLANATION OF PLATES

PLATE 1

1 Marly limestone with algal remains and thalli of *Eothrix alpina* Lombard. Tithonian; Monte Nerone, Italy. × 60.

2 Limestone containing *Aptychus* and molds of Radiolaria in calcite. Upper Jurassic; Island of Maio, Cape Verde Archipelago. × 100.

3–4 Marly limestone containing molds of various species of Radiolaria preserved in chalcedony. Tithonian; Villares, Granada. × 100.

5 Marly limestone filled with *Halobia* fragments. At right, a radiolarian test. Dogger; Villares, Granada. × 100.

6 Marly limestone containing fragments of *Halobia*, with a few "Globigerinas." Bathonian (Dogger) "false breccias"; Majorca. × 100.

PLATE 2

1–2 Zoospores of *Globochaete alpina* Lombard, attached to a slender support. Tithonian; Estepa, Seville. × 200.

3–4 Urn-shaped zoospores, from the same level and locality. × 200.

5–15 Molds of Radiolaria. 5-7, 9, 15, Tithonian; Villares, Granada; × 200. 8, 10-14, Tithonian; Majorca; × 300.

PLATE 3

1–27 Diverse aspects of the zoospores of *Globochaete alpina* Lombard. Tithonian; Majorca and Estepa, Seville. Camera lucida drawings. × 500.

28 Thallus of *Eothrix alpina* Lombard. Tithonian; Majorca. × 200.

29 Radiolaria preserved in iron oxide, in a pelagic limestone. Albian; Larache, North Africa. × 200.

30 Calcite mold of a radiolarian. Tithonian; Majorca. × 200.

31 Marly limestone with *Pithonella ovalis* (Kaufmann). Albian; Majorca. × 300.

32 Molds of Radiolaria in limestone containing *Aptychus*. Upper Jurassic; Island of Maio, Cape Verde Archipelago. × 100.

PLATE 4

1 Limestone composed entirely of the tests of *Nannoconus*. Neocomian; Majorca. × 200.

2 A sporangium(?) of a filamentous alga. Tithonian; Monte Nerone, Italy. × 200.

3 Thallus of *Eothrix alpina* Lombard (upper left) and filaments of *Eothrix* (left). Tithonian; Monte Nerone, Italy. × 200.

4, 6–11, 15–19 Various aspects of the zoospores of *Globochaete alpina* Lombard. Tithonian; Majorca and Estepa, Seville. × 200.

5, 12–13 Thalli of *Eothrix alpina* Lombard. Tithonian; Majorca. × 60 and × 200.

14 Thalli of *Eothrix alpina* and indeterminable remains of diverse organisms. Tithonian; Majorca. × 200.

PLATE 5

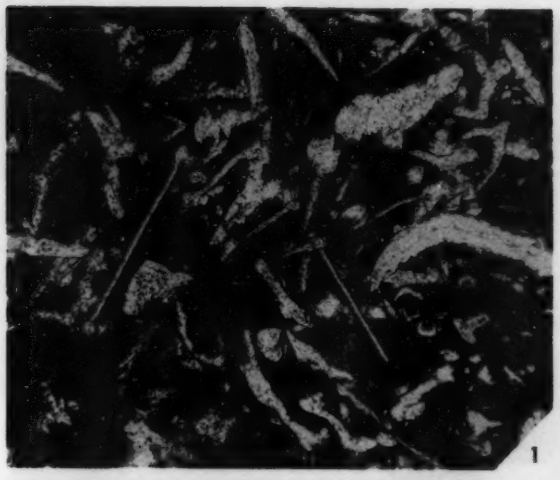
1, 11 Marly limestone with bilobulate zoospores of *Globochaete alpina* Lombard, *Calpionella alpina* Lorenz, and remains of thalli of *Eothrix alpina* Lombard. Tithonian; Monte Nerone, Italy. × 80 and × 200.

2–8, 10 Marly limestones with *Pithonella ovalis* (Kaufmann). Albian; Majorca. 3-8, 10, × 400.

9 *Nannoconus colomi* de Lapparent. Neocomian limestone; Majorca. × 600.

12 Radiolarian plankton. Upper Lias; Majorca. × 40.

13 Reddish limestone with a very pure "globigerinic" plankton. Tithonian; Majorca. × 150.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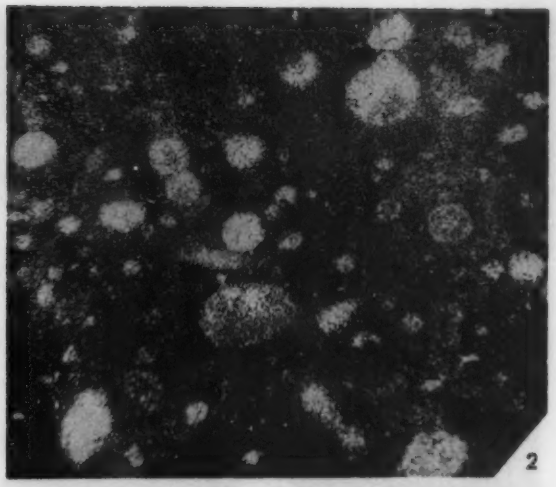
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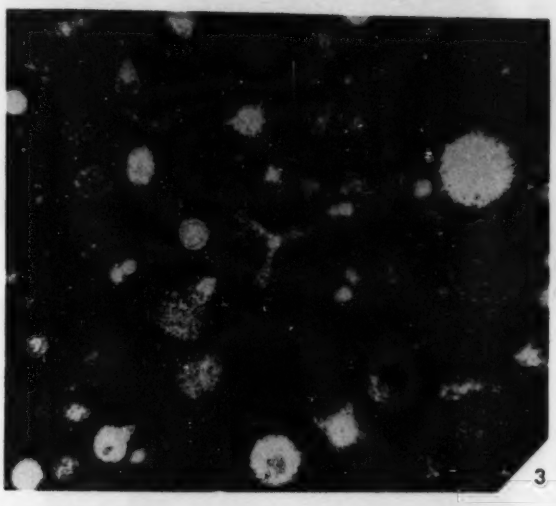
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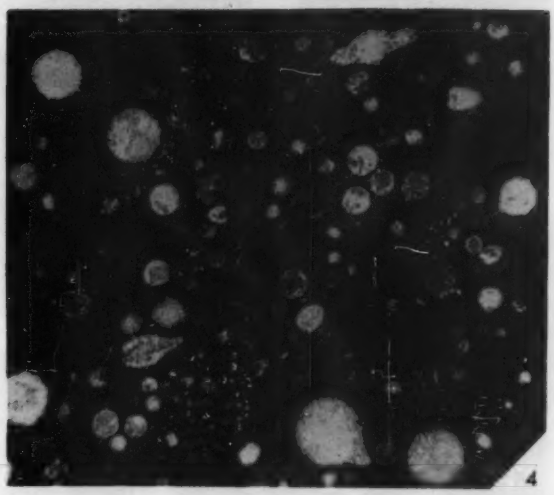
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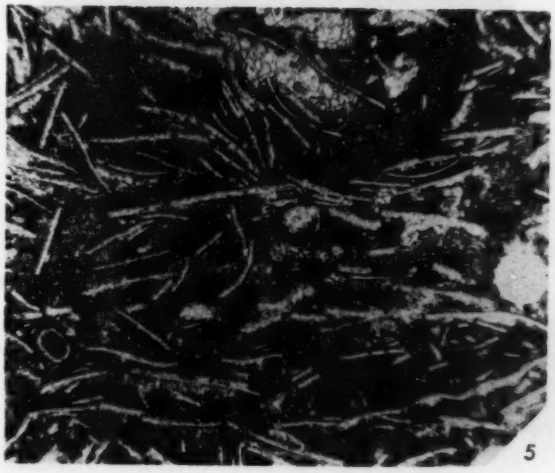
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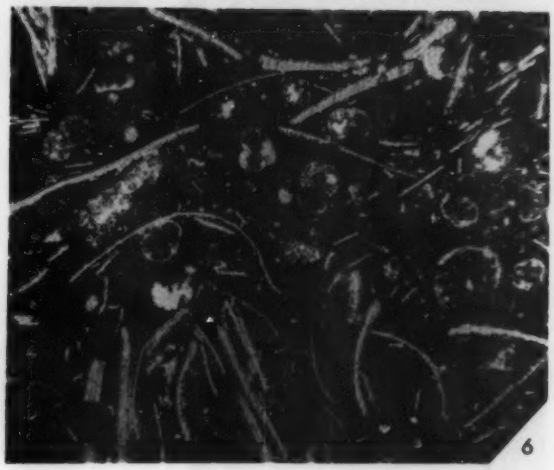
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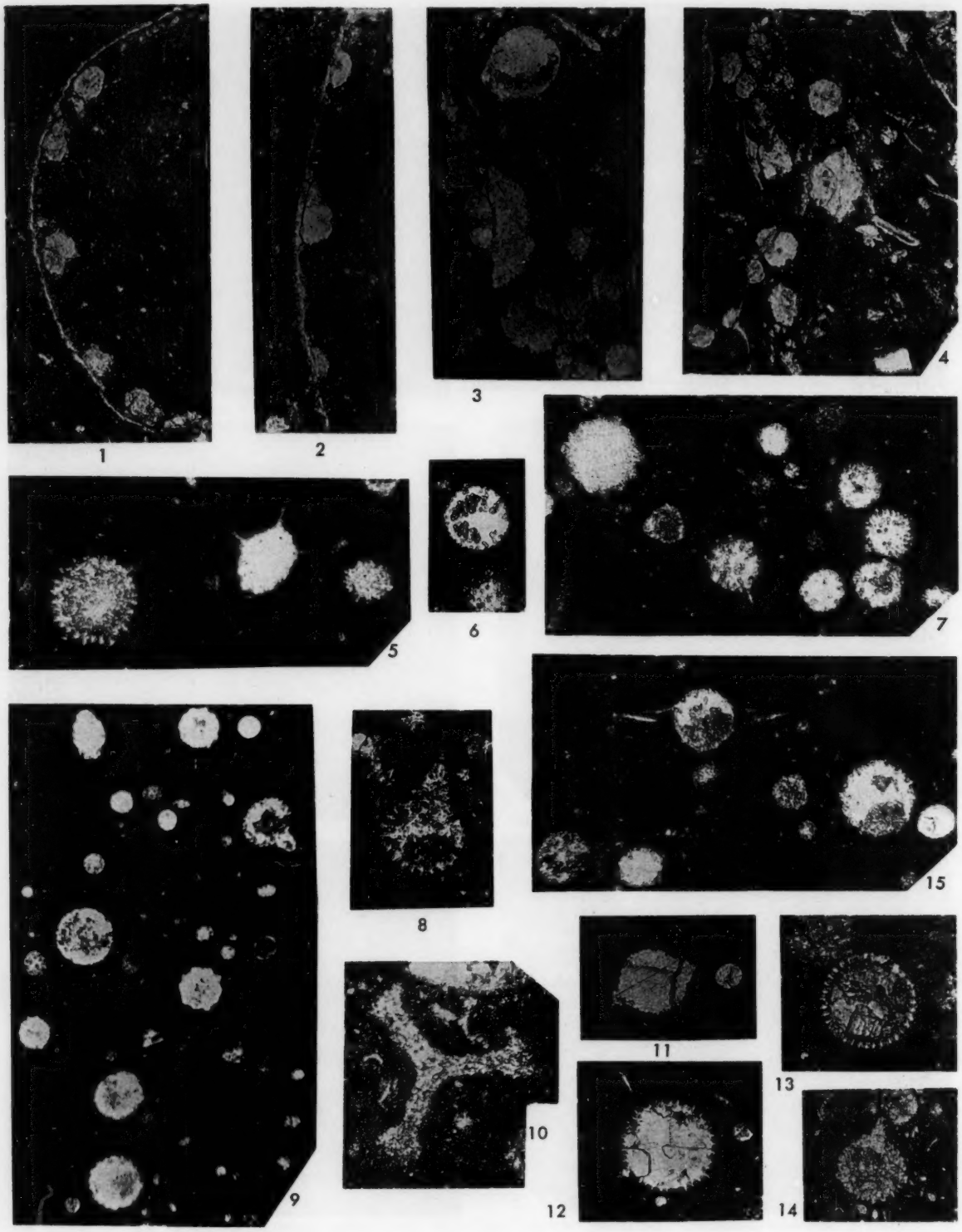
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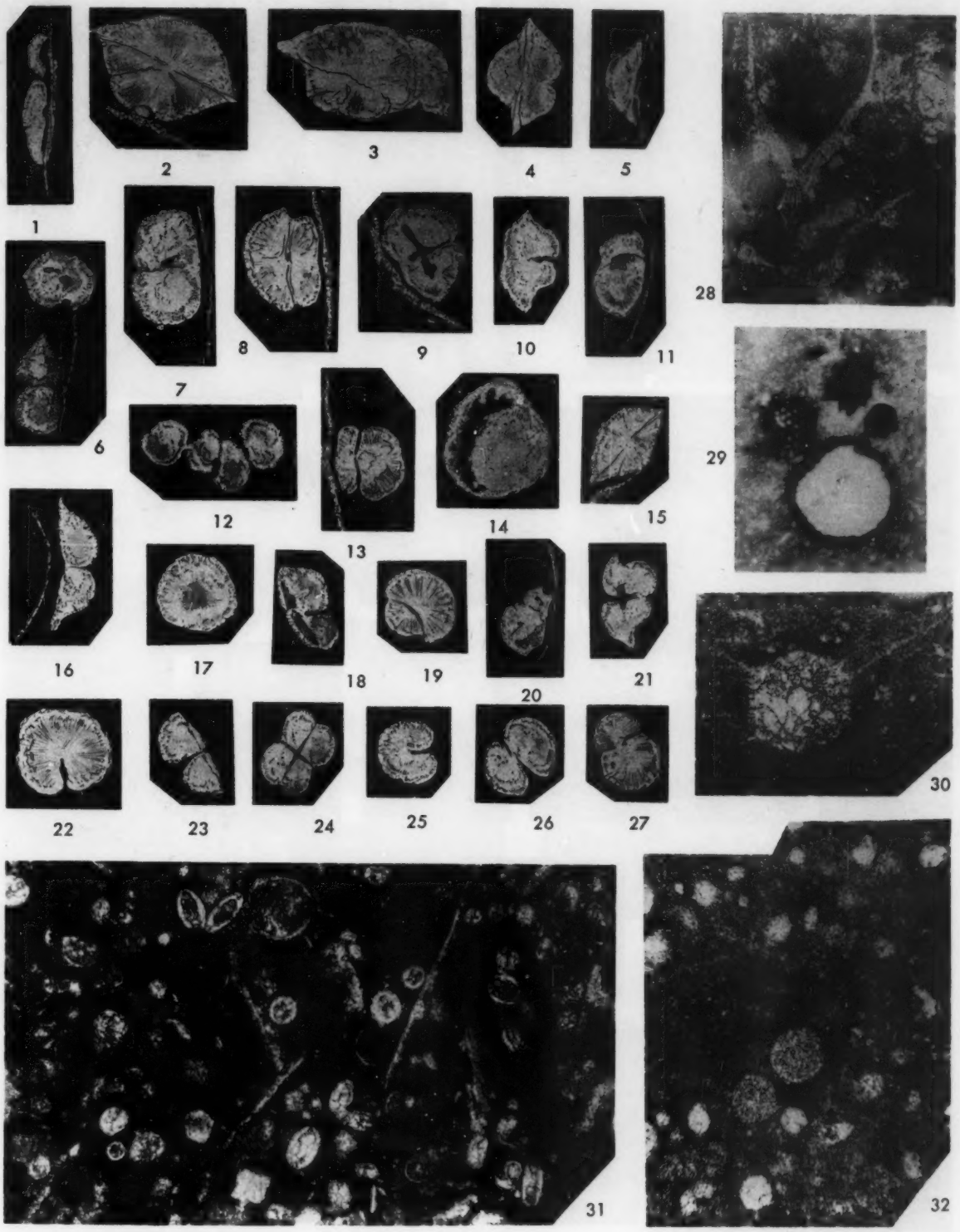
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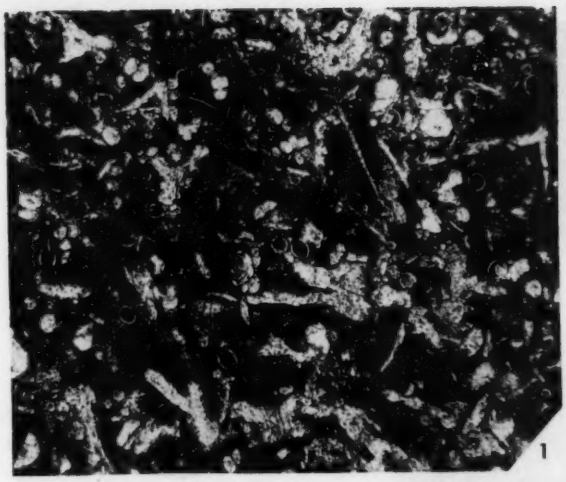
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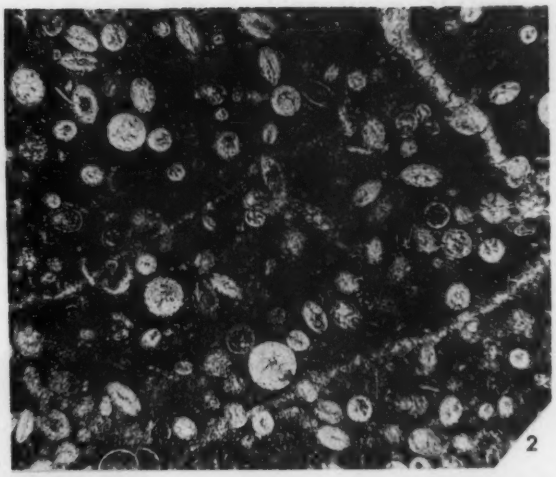
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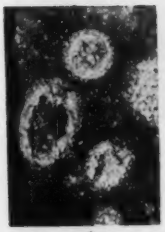
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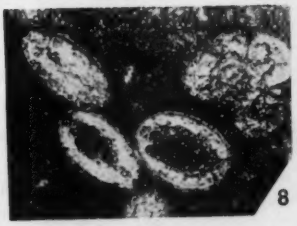
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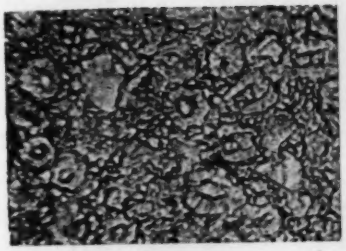
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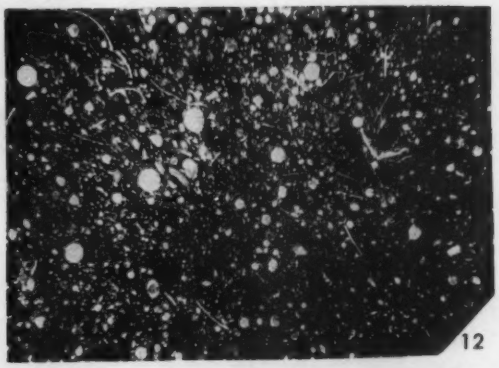
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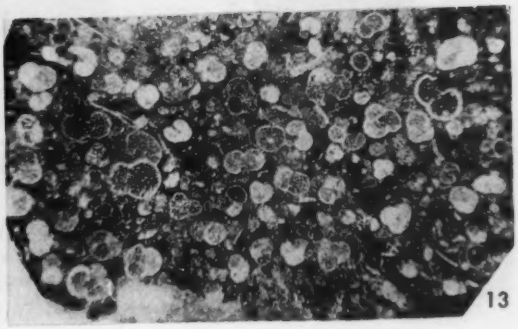
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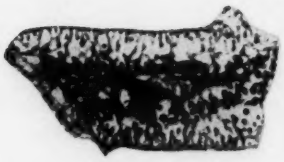
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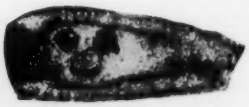
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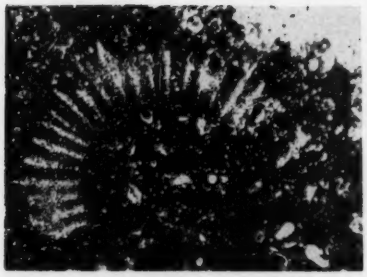
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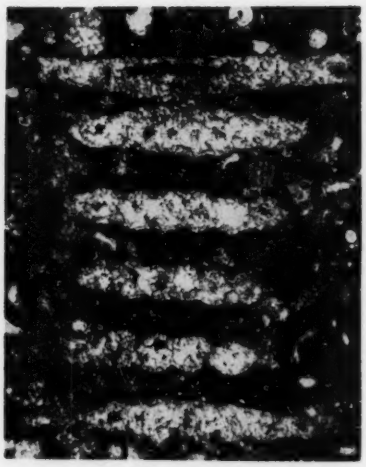
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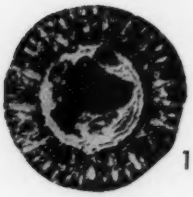
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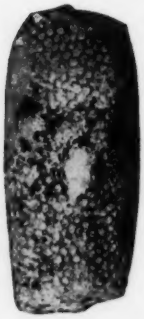
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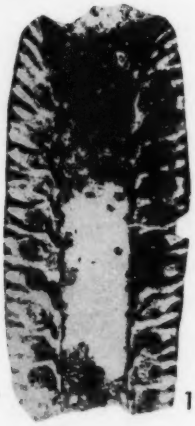
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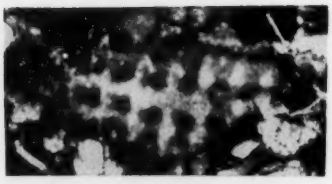
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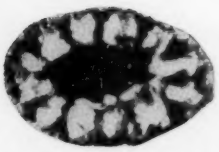
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(for explanation please turn to page 131)

ABSTRACT: *Calcareous algal floras are listed from the Permian of northern Iraq, the Upper Jurassic of Qatar (Persian Gulf), the Lower and Upper Cretaceous, Paleocene and Middle Eocene of northeastern Iraq, and the Paleocene and Middle Eocene of southwestern Iraq. These calcareous algae are discussed in connexion with their distribution elsewhere. New species of* Ovulites, Clypeina, Cymopolia *and* Trinocladus *are described from the Paleocene of northeastern Iraq.*

Fossil calcareous algae from the Middle East

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Iraq Petroleum Company, Ltd.
London

INTRODUCTION

In the Middle East a thick series of predominantly calcareous sediments extends from the Upper Palaeozoic to the mid-Tertiary, and contains many horizons representing ancient, shallow, clear-water, limy environments in the Tethys, suitable for the growth of calcareous algal floras. The present paper is intended to be on the lines of Pfender's excellent study on the fossil algae of Egypt and the Mediterranean (Pfender, 1940), but deals with floras from Iraq, and from Qatar on the Persian Gulf. This investigation has been carried out mostly on thin-section material, a method often criticised (see Elias, 1947). However, much information may be gleaned in this way from material primarily collected for stratigraphical purposes in relatively inaccessible areas, and not always recognised in the field as fossiliferous. Such information should not be disparaged because it is incomplete, providing that its limitations are recognised. It has been supplemented in the present study by the examination of solid specimens wherever available, and all species described as new are represented by both solid and thin-section material. My thanks are expressed to the Management and Chief Geologist of Iraq Petroleum Company, Ltd., for permission to publish this account; to Dr. F. R. S. Henson, the Company's Senior Research Geologist, who entrusted me with this study; to Mr. W. Sugden, Area Geologist at Qatar, for material sent to me; and to Mr. W. N. Edwards, Keeper of Geology, British Museum (Natural History), for facilities granted for examination of the national collections and for his kind interest in my work.

PERMIAN

The Upper Permian limestones of Ora and Harur, near the Turkish frontier in Mosul Liwa, northern Iraq, have yielded a distinctive algal assemblage consisting of *Mizzia velebitana* Schubert, *Gymnocodium bellerophontis* (Rothpletz) and some seven other species of this genus, *Diplopora* sp., and *Macroporella*. This microflora, and its relationship to those from other areas, has been more fully described elsewhere (Elliott, 1955).

TRIASSIC AND JURASSIC

The Triassic of the mountain zone of northeastern Iraq, which, in view of the rich dasyclad flora of the same system in Austria and the Balkans and the correspondence of the European and Iraqi Upper Permian, might have been expected to have been similarly rich, is almost barren of algae and has not yielded a single determinable dasyclad, though spongiostromoid algal growth-forms occur at certain horizons. The Jurassic is also most disappointing. To the south, however, in the Qatar Peninsula on the shores of the Persian Gulf, subsurface Jurassic is known from the deep borings in the Dukhan oil field. In the upper part of the Upper Jurassic, a small microflora consists of *Clypeina jurassica* Favre, *Clypeina* cf. *hanabatensis* Yabe and Toyama, and *Salpingoporella annulata* Carozzi. Of these, *C. jurassica* is known from various horizons in the Upper Jurassic of Switzerland, southern France, Greece and Algeria (Morellet, 1951); it was first recorded from Qatar by Henson in an unpublished report. The second species, usually slightly larger and

distinguished by possessing 22 to 24 sporangial chambers against the 11 to 20 of *C. jurassica*, is compared with *C. hanabatensis* from the Upper Jurassic of Japan. Although it does not reach the size or number of sporangial chambers per whorl of the latter species (3.15-4.0 mm. and about 27, respectively), it seems unnecessary to introduce a third name for what is probably local variation in size.

Salpingoporella annulata was identified by Carozzi from photographs sent to him by the writer. In the Qatar specimens the proportionally thick calcite of the tube-walls has been removed in solution and only partly filled by secondary crystallisation, but dimensions and structures correspond (see Carozzi, 1953). *Salpingoporella annulata* occurs in Europe in the Portlandian of Switzerland and the Portlandian—Purbeckian of southern France (Carozzi, 1953; Collet and Carozzi, 1954).

CRETACEOUS

In the mountain zone of northeastern Iraq, various microfloras are distinguishable at different levels in a thick, largely calcareous, Cretaceous succession.

At a level faunally dated as about Valanginian—Hauterivian there occur *Actinoporella podolica* (Alth) (pl. 1, fig. 1); *Clypeina parvula* Carozzi; *Salpingoporella* cf. *mühlbergii* (Lorenz); and *Acicularia* sp., the first two being much the more common. At the Barremian—Aptian level, possibly extending to the Albian, the latter two are accompanied by abundant but very fragmentary *Munieria baconica* Deecke, and a tiny, rare species of *Triploporella*. These ranges are local, for *A. podolica* was described from the Portlandian of Podolia (Alth, 1878, 1882); *M. baconica* from the Aptian of Hungary (Deecke, 1883; Taeger, 1936); and *C. parvula* from the Purbeckian of Switzerland, where it is accompanied by both of the others (Carozzi, 1948). The maximum range of algal species is often greater than their local ranges, which are probably facies-controlled. *S. mühlbergii* was originally described and listed from the Barremian—Aptian of Switzerland and central Europe (Lorenz, 1902; Pia, 1918); the Iraq specimens are usually smaller, but appear similar to the European form in section. The little *Triploporella*, from the Aptian—Albian, is much smaller than the Cenomanian *T. fraasi* Steinmann and *T. apenninica* Baretti, from Lebanon and Italy, respectively (Steinmann, 1899; Baretti, 1922), but shows similar structure. The Iraq *Acicularia* from the upper horizon is comparable with *A. antiqua* Pia (Pia, 1936*a*) from the Cenomanian—Turonian of northern Africa.

Higher in the Cretaceous, badly recrystallised fossils, apparently of a large dasyclad, occur not uncommonly from the Cenomanian to the Campanian; these were suspected to be of *Neomeris* sp., and a single, fortunately well-preserved section (pl. 1, fig. 7) permits close comparison and probable identity with *N. cretacea* Steinmann (Steinmann, 1899, cf. fig. 15). This was first described from the Cenomanian—Turonian of Mexico; Pia (1936*a*) mentions *Neomeris* spp. indet. from the same horizon in Libya, and Pfender (1940) records a *Neomeris* sp. from the Upper Cretaceous of Morocco, Spain, and southern France. Several species may be represented by the recrystallised Iraq specimens; there is at least one distinct from *N. cretacea*, but it cannot be described from the material available.

Other algae are rare in the Upper Cretaceous, but representatives of the genera *Archaeolithothamnium*, *Amphiroa*, *Parachaetetes* and *Solenomeris* (the latter the first pre-Tertiary record, other than from the Danian; see Pfender, 1926; Douvillé and O'Gorman, 1930) have been noted, all in the Campanian. The curious *Pseudolithothamnium album* Pfender, already recorded as ranging from Lower Cretaceous to Eocene and possibly Oligocene (Pfender, 1937), occurs in the Campanian—Maestrichtian.

PALEOCENE

The Paleocene of northeastern Iraq occurs in two facies: calcareous, and a subordinate sandy development. The latter yields new species of *Trinocladus* and *Ovulites;* the former a larger flora, containing *Acicularia* spp. (pl. 1, figs. 11-12), *Archaeolithothamnium* cf. *aschersoni* (Schwager), *Clypeina* sp. nov., *Cymopolia* cf. *elongata* (Defrance), *C.* sp. nov., *C. (Karreria)* sp., *Dissocladella savitriae* Pia (pl. 1, fig. 2), *Griphoporella arabica* Pfender, *Halimeda nana* Pia (pl. 1, fig. 3), *Jania* sp., *Lithophyllum* sp., *Lithothamnium* sp., the new species of *Ovulites*, *Parachaetetes asvapatii* Pia, and *Pseudolithothamnium album* Pfender.

The new species are described first to facilitate subsequent discussion:

Genus OVULITES Lamarck, 1816

Ovulites morelleti Elliott, new species
Plate 1, figures 4-6

Description: Hollow elongate-tubular bodies, with slight terminal clubbing, an opening at both ends; length up to 1.77 mm.; diameter normally up to 0.33 mm., exceptionally greater; wall-thickness normally 0.025—0.050 mm., exceptionally greater; wall

finely perforate, pores straight and radial, diameter of pores 0.010—0.015 mm.

Syntypes: The specimens figured in plate 1, figures 4-6, from the Paleocene of Banik (Mosul Liwa), Koi Sanjak (Erbil Liwa), and Surdash (Sulemania Liwa), Iraq; Reg. nos. W1.11563, 11563A, 10270A, Geol. Coll. Iraq Petroleum Co., Ltd., London.

Other material: Numerous solid and thin-section specimens from the Paleocene of northern and northeastern Iraq.

Remarks: The units or segments of this little codiacid occur abundantly in the Kurdistan Paleocene. When compared with species from the French Middle Eocene, described in detail, reconstructed and compared with the Recent *Penicillus* by Munier-Chalmas (1881) and Morellet (1939), they are seen to be closest to *O. elongata* Lamarck, a species with distinctive delicate elongate units. This is surprising, as it is the larger and coarser *O. margaritula* Lamarck that has the greatest geographical range, extending into Italy and Hungary. The units of *O. morelleti*, however, are usually somewhat shorter and thicker-walled, and of slightly greater average diameter, than those of the French species. Moreover, they are accompanied by a small minority of thickened ovoid or pyriform units, which suggests that the plant of *O. morelleti* showed some variety of unit shape, as shown for *O. margaritula* and *O. ochlerti* (Munier-Chalmas), but not for *O. elongata*, in reconstructions (Munier-Chalmas, 1881). In *O. morelleti* these special units are few and were probably confined to the basal joints. The unnamed *Ovulites* sp. mentioned by Morellet (1940) from the French Montian, at about the same level as some of the Iraq specimens, was described as similar to elongate units of *O. margaritula;* this description would apply to typical *O. morelleti.*

The species is dedicated to my deceased friends MM. L. and J. Morellet, the distinguished workers on fossil calcareous algae.

Genus CLYPEINA Michelin, 1845

Clypeina merienda Elliott, new species
Plate 1, figures 8-9

Description: Fertile whorls with external diameter of 2.5 mm. or more; diameter of central cavity 1.0 mm.; whorl consisting of about 50 or more radiating hollow tubes or compartments, set in one horizontal plane, united laterally except possibly at the terminations, which may be expanded; internal diameter of tubes approximately 0.050 mm.; tubes each communicating with the central cavity by a pore; calcification thickest around central cavity, extending downward to meet the next whorl. Up to six whorls seen together, the horizontal planes of one mid-whorl and the next being about 0.39—0.52 mm. apart.

Syntypes: The specimens figured in plate 1, figures 8-9, and one other specimen, from the Paleocene of Sirwan (Sulemania Liwa) and Koi Sanjak (Erbil Liwa); Reg. nos. W1.4283A, 4288A, 11567B, Geol. Coll. Iraq Petroleum Co., Ltd., London.

Other material: Several thin-section specimens from the Paleocene of northeastern Iraq.

Remarks: This large Tertiary *Clypeina* (*C. marginoporella* Michelin, *C. stelliformis* Morellet, and *C. pezanti* Morellet, from the French Eocene, have external whorl-diameters of about 1 mm.) somewhat recalls the large *Orioporella* from the Montian of France and the Danian of India in size and in the horizontally-disposed whorls, but there is no trace of the latter's pores on upper and lower surfaces of the sporangial tubes or compartments. The Iraq fossil is unusual for a *Clypeina* in the large size of the nearly horizontal whorls, the large central cavity, and in the fact that a majority of the specimens examined show several whorls still united. However, all of these phenomena have been recorded in large examples of the Jurassic *C. grandis* from Algeria (Morellet, 1951), from which it differs in the much larger number, at least double, of radial compartments.

The trivial name is from the Spanish *merienda,* a luncheon or light meal, and refers to the cake-stand appearance of the plant.

Genus CYMOPOLIA Lamouroux, 1816

Cymopolia kurdistanensis Elliott, new species
Plate 1, figures 13-15

Description: Tubular cylindrical dasyclad units, the ends rounded; units up to 2.75 mm. in length; external diameter 0.75 mm. (exceptionally 1.0 mm.); internal diameter 0.375 mm. (d/D = 50% approximately); closely-set fused successive whorls of rather crowded structure; primary branch with four sterile secondary branches and one sporangium; about 28 globular sporangia per whorl (sporangium diameter 0.050—0.070 mm.); the primary and secondary branches directed upward and outward, respectively, with regard to the main axis of the unit; external surface pitted with close rounded polygonal depressions, which are the expanded openings of the secondary branches.

Syntypes: The specimens figured in plate 1, figures 13-15, from the Paleocene of Banik (Mosul Liwa), Iraq; Reg. nos. W1.11567A, 11558A, Geol. Coll. Iraq Petroleum Co., Ltd., London.

Other material: Several thin-section specimens from the Paleocene of northeastern Iraq.

Remarks: This dasyclad bears considerable resemblance in thin section to *Indopolia* from the Indian Danian (Pia, 1936*b*); this, however, is described as having two sporangia and two secondary branches per primary branch. The Iraq fossil may be distinguished from the associated *Cymopolia elongata* (Defrance) by its smaller average size and smaller, perhaps more crowded structures, particularly the lesser distance internally between the openings of the primary branches: 0.16—0.18 mm. against 0.31 mm.

Genus TRINOCLADUS Raineri, 1922

Trinocladus perplexus Elliott, new species
Plate 1, figures 16-18

Description: Tubular-cylindrical, slightly tapering tube, the plant probably slender club-shaped in life. Length, fragments, up to 1.56 mm.; external diameter up to 0.39 mm. (d/D = 40-55%). Wall perforated by branching pores; about four whorls per 0.25 mm. vertical measurement. Each whorl contains from seven to ten primary branches, with internal rounded rectangular openings. Traced outward in the wall-thickness, the branches each divide into four secondary branches. In the larger specimens, which are later-formed portions of the plant, these secondary branches each divide into four branchlets, which emerge to form a close pattern of fine pores on the external surface of the fossil. No definite sporangial cavities are to be seen, but the secondary branch-cavities are swollen.

Syntypes: The specimens figured in plate 1, figures 16-18 from the Paleocene of Koi Sanjak (Erbil Liwa) and Surdash (Sulemania Liwa), northeastern Iraq; Reg. nos. W1.10270B, DM.775A and B, Geol. Coll. Iraq Petroleum Co., Ltd., London.

Other material: Several thin sections and numerous fragments of solid specimens from the Paleocene of northeastern Iraq.

Remarks: This plant is obviously a thyrsoporellid. From previously described species of *Trinocladus*, *Dissocladella* and *Thyrsoporella* it may be distinguished by the percentage relation of internal to external diameter, details of the branching and general characters. In allocating it to a genus within the group, it may be noted that *Dissocladella* shows secondary branching, *Thyrsoporella* and *Belzungia* tertiary branching, and *Trinocladus* one following the other as growth proceeds; it is therefore referred to the latter. It may be distinguished from the type, *Trinocladus tripolitanus* Raineri (Pia, 1936*a*) from the Cenomanian of North Africa, by its smaller size and proportionally wider central stem-cavity. The thyrsoporellids are a closely-knit group and much more information is needed to give a truly phylogenetic classification, if this is possible.

Of the various other species listed, *Archaeolithothamnium aschersoni* was described from the Lower Eocene of Egypt (Schwager, 1883) and has been recorded from the Danian of Morocco (Pfender, 1938). *Cymopolia elongata* ranges from Paleocene to Oligocene in France, and species of *C. (Karreria)* are known from the uppermost Cretaceous or lowest Tertiary of Tibet (Morellet, 1916) and the Eocene of France (Morellet, 1913, 1922). *Dissocladella savitriae* was described from the Danian of India (Pia, 1936*b*); solid specimens of this species confirm the presence of the annulated external surface as reconstructed by Pia (op. cit., text-fig. 43). *Griphoporella arabica* is known from the Lower Eocene of Morocco and the Middle Eocene of Syria and Egypt (Pfender, 1940). *Halimeda nana*, described from the Danian of Morocco (Pia, 1932), has been recorded from the Paleocene of India (Rao, 1948). *Parachaetetes asvapatii* was described from the Danian of India (Pia, 1936*b*). It may be noted that *Elianella elegans* Pfender, recorded from the Upper Cretaceous of the Carpathians, the Paleocene of Madagascar, and the Nummulitic of Venezuela, the Pyrenees, the Alps and Turkey, appears very similar to Pia's *P. asvapatii*, from the figures, dimensions and descriptions given (Pia, 1936*b*; Pfender and Basse, 1948). Whatever the nomenclatural results of a study of the type materials, the Iraq solenoporoid is very similar, too. The range of *Pseudolithothamnium album* has already been given above under its Cretaceous occurrence, the affinities of the new species described here have also been given, and none of the genera represented by an unnamed species is abnormal for the Paleocene.

From all this it will be seen that the affinities of the flora are overwhelmingly with those of other presumed warm-water latest Cretaceous to early Tertiary Tethyan occurrences, and that the flora supports the faunal evidence as to the wide geographic range of Tertiary Tethyan organisms. The melobesoids and solenoporoids on the one hand, and the dasyclads and to a certain extent the codiacids on the other, tend

to be mutually exclusive, a fact probably indicating similar ecologic preferences to those of the present day.

In the desert of southwestern Iraq, the Paleocene limestones yield abundant remains of a poorly preserved little dasyclad that has also been noted at the same horizon in a boring in the Zubair oil field near Basra. This alga is probably the same as *Dactylopora* sp. of Schwager (1883) from the Lower Eocene of Egypt, identified as *Dissocladella* sp. by Pia (1936*b*). It shows about ten or twelve pores per whorl, each dividing into four, so that in horizontal or vertical section alike they appear as simple bifurcating canals, but the material available is not well enough preserved for description.

A codiacid from this horizon appears to be referable to *Boueina* rather than to *Halimeda*, although the former is usually taken as Cretaceous and the latter as Tertiary.

EOCENE

The Lower Eocene of northeastern Iraq has yielded the long-ranging *Cymopolia* cf. *elongata* (Defrance). *Thyrsoporella silvestrii* Pfender occurs in the Middle Eocene of this area. The latter is common, though usually poorly preserved, in the Middle Eocene of southwestern Iraq. Cuvillier's figures (1930, pl. 11) of a thyrsoporellid from the Lutetian of Egypt were recognised as such by Pia (1936*b*), and this occurrence was compared by Pfender (1940) with a Somaliland alga figured by Silvestri (1938, 1939). Pfender compared the Tethyan form in detail with the Paris Basin *T. cancellata* Gümbel (Morellet, 1913), and named the former *T. silvestrii*, recording it also from Turkey, Syria, the Pyrenees and Madagascar. To this species (pl. 1, fig. 10) the present writer refers all the Iraq material examined. It may be noted that it is very difficult to discriminate between *Thyrsoporella* and the similar, allied, but segmented *Belzungia* in thin section. The only thyrsoporellid section from Iraq which suggested *Belzungia* during the present work was from northeastern Iraq, and this was the area from which Morellet, in an unpublished record available to the writer, recorded a thyrsoporellid reminiscent of *Belzungia*. Solid specimens of *T. silvestrii* from various localities are necessary to check this point.

CONCLUSION

It will be seen from the above records that calcareous algae are not uncommon in the Middle East, and many are no doubt yet to be described. Meanwhile, the present survey is offered as a companion paper to Pfender (1940), and it is hoped that it will help to bridge the gap in our knowledge of these fossils between those of the better-known Mediterranean countries and those of the Indian Peninsula.

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EXPLANATION OF PLATE 1

1 *Actinoporella podolica* (Alth)
Horizontal section through one verticil, × 30. Lower Cretaceous (Valanginian-Hauterivian); Jabal Gara, Mosul Liwa, northern Iraq. W1.6379.

2 *Dissocladella savitriae* Pia
Transverse section to show sporangial cavities and radiating canals, × 28. Paleocene; Banik, Mosul Liwa, northern Iraq. W1.11571.

3 *Halimeda nana* Pia
Longitudinal section through a single unit, × 28. Paleocene; Banik, Mosul Liwa, northern Iraq. W1.11567.

4 *Ovulites morelleti* Elliott, n. sp.
Two isolated units from the Paleocene of northeastern Iraq, × 28. W1.11563A.

5 *Ovulites morelleti* Elliott, n. sp.
Oblique-vertical section, × 50. Paleocene; Banik, Mosul Liwa, northern Iraq. W1.11563.

6 *Ovulites morelleti* Elliott, n. sp.
Transverse section, × 50. Paleocene; Koi Sanjak, Erbil Liwa, northeastern Iraq. W1.10270A.

7 *Neomeris cretacea* Steinmann
Oblique-transverse section, × 28. Upper Cretaceous (Campanian-Maestrichtian); Gal-i-Mazurka, Mosul Liwa, northern Iraq. W1.6911.

8 *Clypeina merienda* Elliott, n. sp.
Horizontal-tangential section through incomplete whorl, × 28. Paleocene; Sirwan, Sulemania Liwa, northeastern Iraq. W1.4288A.

9 *Clypeina merienda* Elliott, n. sp.
Vertical-tangential section through several whorls, × 28. Same locality and horizon as fig. 8. W1.4283A.

10 *Thyrsoporella silvestrii* Pfender
Transverse section, × 30. Middle Eocene; Galaib, southwestern Iraq. HR.635.

11 *Acicularia* sp. 1
Random sections of spicules, × 50. Paleocene; Sirwan, Sulemania Liwa, northeastern Iraq. W1.4214.

12 *Acicularia* sp. 2
Random section of spicule, × 50. Same locality and horizon as fig. 11. W1.4266.

13 *Cymopolia kurdistanensis* Elliott, n. sp.
Transverse section partly in plane of sporangial ring, × 28. Paleocene; Banik, Mosul Liwa, northern Iraq. W1.11558A.

14 *Cymopolia kurdistanensis* Elliott, n. sp.
View of exterior surface of unit, × 20. Same locality and horizon as fig. 13. W1.11567A.

15 *Cymopolia kurdistanensis* Elliott, n. sp.
Vertical section of unit, × 28. Same specimen as fig. 14.

16 *Trinocladus perplexus* Elliott, n. sp.
Fragment of isolated tube showing pores of secondary branching, × 28. Paleocene; Surdash, Sulemania Liwa, northeastern Iraq. DM.775B.

17 *Trinocladus perplexus* Elliott, n. sp.
Vertical section of fragment to show triple branching, × 50. Same locality and horizon as fig. 16. DM.775A.

18 *Trinocladus perplexus* Elliott, n. sp.
Transverse section, × 50. Paleocene; Koi Sanjak, Erbil Liwa, northeastern Iraq. W1.10270B.

ABSTRACT: *A new microfaunal diagram is described, which permits the quantitative composition of microfaunas to be presented in a very compact form. Percentages of planktonic and benthonic individuals, and individual percentages for planktonic genera and species, can be plotted in a single diagram. Examples showing the possibility of using such a diagram for ecologic and correlation purposes are given. Conclusions as to the wide range of application of this method are discussed.*

A new type of microfaunal diagram

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INTRODUCTION

Studies on fossil microfaunas have become very numerous during these latter years, chiefly as a result of their use in the petroleum industry. Consequently, our knowledge of small fossils has undergone a rapid evolution. Studies on Recent micropopulations are also in a developmental stage, especially in relation to investigations of the sea bottom by coring, even in waters of considerable depth.

Microfaunal studies have proved to be most important with regard to ecology and the interpretation of environmental conditions and facies, both in Recent and in older sediments. All these researches have led to the development of new techniques and methods of study. New quantitative elements have been added to qualitative taxonomic criteria in order to obtain a suitable representation of the composition of micropopulations. In the present work, I have not taken into consideration all quantitative biometric data.

Ellison (1951) demonstrated that a mathematical approach to environmental interpretation by quantitative studies of micropopulations promises to be the best approach to paleoecological investigations. Quantitative relations of various microfossil groups, families as well as genera and species, are usually taken into consideration in modern investigations of sea-bottom sediments. In the study of the foraminifera, the relationship between planktonic and benthonic individuals is particularly interesting.

In quantitative studies on foraminifera, the following elements are usually taken into account:

Number of individuals per gram of sediment (foraminiferal number);

Percentage of planktonic and benthonic individuals;

Percentage of individuals per benthonic family, per genus, and per species;

Number of benthonic species per gram of sediment.

In this respect, I think it advisable to use the ratio between the number of benthonic species and benthonic individuals. This ratio may be expressed as a percentage, but is available only when a sufficient number of individuals for statistical study is available. All of these quantitative elements provide objective, uniform data for examination and comparison of various microfaunal assemblages.

GRAPHIC PRESENTATION OF MICROFAUNAL DATA

All of the elements listed above may be plotted graphically so as to present the results visually and in a uniform manner. The same methods and diagrams used for statistical purposes have been introduced for the graphic presentation of quantitative microfaunal data. Frequency variations of single species of foraminifera or of other micro-organisms are commonly shown on a "range chart." Such a chart permits one to follow the succession of species and their frequency variations in a bore hole or in a stratigraphic sequence. The use and application of "range charts" have recently been discussed by Bursch (1950).

Different graphic presentations have been introduced to show quantitative data for families, genera, and species of foraminifera. Norton (1930) plotted rectangular histograms to show the percentages of different species and varieties per family of foraminifera; other histograms show the percentage of abundance of individuals in families of foraminifera in relation to the bathymetric distribution. Rau (1948) plotted a bar diagram showing relative abundance of the various genera of foraminifera in shales. Some authors (Bandy, 1954) indicate the frequencies of genera and species, and the total number of foraminiferal species in relation to ecological or chronological changes, by means of line diagrams instead of rectangular blocks. Low-

man (1949) and Bandy (1953) plotted the data along with cumulative frequency graphs, in order to depict graphically the variations of foraminiferal frequency in relation to ecologic changes. This latter graphic presentation is highly significant, especially if the data for a few species and genera are plotted.

An attempt to present the composition of foraminiferal faunas for ecologic purposes by means of circular diagrams known as "pie diagrams" was made by Renz (1948). This author subdivided a circle into portions corresponding to percentages of individuals per family, in both planktonic and benthonic assemblages. These diagrams certainly show general quantitative aspects of microfaunas. Actually, however, we can observe only areal subdivisions and relationships corresponding to the percentages of families, and from such subdivisions we must go back to numerical elements. Moreover, the percentages of both planktonic and benthonic individuals have been calculated together. These elements, however, should preferably be kept separate.

A new type of circular foraminiferal diagram was plotted by Ciry, Tintant, and Charegron, and reported by Piveteau (1952). It was designed in an effort to avoid the disadvantages mentioned above. This diagram consists of three concentric circles. The innermost circle was subdivided into portions corresponding to percentages of planktonic and benthonic individuals. The middle circle was subdivided on the basis of individual percentages per family. The outermost circle was subdivided on the basis of individual percentages per genus. This diagram is more complete than the "pie diagram," but nevertheless, areal subdivisions have been resorted to in this case as in all circular diagrams.

NEW MICROFAUNAL DIAGRAM PRESENTATION

I would like to suggest a new type of diagram that might represent, better than the previous types, quantitative data relating to microfaunas. I have taken into consideration the following elements, when working with foraminiferal faunas:

Percentage of planktonic and benthonic individuals;

Percentage of individuals per benthonic family;

Percentage of individuals per planktonic genus and per species.

The new diagram differs from the others in being in the form of a square. It is constructed as follows:

A 10-centimeter square is drawn on ordinary cross-ruled millimeter paper (see text-figs. 1-2). Both the vertical and the horizontal sides are subdivided into 100 parts of 1 mm. each. The opposite vertical sides are then joined by a horizontal line drawn at a distance from the top of the square corresponding to the percentage value of benthonic individuals. In this way, the original square is divided into two rectangles that correspond, respectively, to the benthonic (upper) and the planktonic (lower) individual percentages.

Let us first consider the upper rectangle. The values of percentages of individuals per benthonic family are plotted along its two horizontal sides, until the value of 100 per cent is reached, thus introducing the criterion of a cumulative frequency graph. The percentage subdivisions traced on the two opposite horizontal sides are then joined by means of vertical lines. The original rectangle is thus divided into as many rectangles as there are foraminiferal families under consideration.

Let us now consider the lower rectangle (planktonic individuals). Subdivisions are drawn in the same way as in the upper rectangle, except that in this case the percentage values correspond to individual percentages per genus, instead of per family. Further subdivisions by species can be introduced by means of vertical segments joining the two horizontal sides of the generic rectangles, upon which cumulative frequency percentages per species have been plotted (text-fig. 2, *b*, *i*, and *e*). Similar subdivisions may also be made within the benthonic family rectangles.

In summary, the original square was horizontally subdivided into two rectangles corresponding to benthonic and planktonic individual percentages. Both rectangles were vertically subdivided into other rectangles, corresponding to individual percentages per benthonic family and to individual percentages per planktonic genus and species.

When all the data have been plotted on the diagrams, so that the different elements may be clearly distinguished, graphic symbols corresponding to the various families and genera are introduced. In routine work, the use of colors has proven to be simpler and visually more effective than symbols. In order to make the diagrams more complete, Roman numerals have been used for the benthonic families, while Arabic numerals correspond to planktonic genera, and small letters indicate planktonic species. Blank rectangles indicate the total individual percentages per benthonic family and per planktonic genus that are represented by a percentage value lower than 1.0. In the diagrams presented here, the foraminiferal families are arranged in systematic order, according to Cushman's classification.

USE OF THE NEW DIAGRAM

The following diagrams of foraminiferal faunas are introduced here in order to show their application:

Diagrams of Recent benthonic foraminifera ranging from 53 to 680 meters in depth. These are intended to show the quantitative composition of the microfauna in relation to variations in sea depth (text-fig. 1).

Diagrams of fossil foraminifera ranging in age from lower to middle Pliocene, collected from a continuous, uniform lithologic unit. These are intended to show quantitative variations in the microfauna in relation to chronologic changes (text-fig. 2).

Diagrams of fossil foraminifera collected from two different stratigraphic sections of the same age outcropping at about 300 kilometers from each other. These are intended to show the possibility of comparison and correlation, even at great distances (text-fig. 2).

Text-figure 1: Foraminifera collected from the Gulf of Maine to Maryland (U. S. A.) have been considered. Data are from Parker (1948): "New Jersey traverse section (Table 8)," sample no. 1243, from a depth of 53 meters; and "Martha's Vineyard section (Table 10)," samples from depths of 228 meters, 309 meters, 393 meters, 469 meters, and 680 meters. Examination of the diagrams shows that:

The percentage of planktonic individuals increases strongly from 53 meters to 228 meters, and continues to increase in relation to increasing depth.

The percentage of *Globigerina bulloides (b)* decreases gradually in relation to increasing depth.

The percentage of *Globigerina eggeri (e)*, on the contrary, continues to increase with depth.

Anomalinidae (XII) are very numerous at 53 meters, among the benthonic forms, but they decrease with increasing depth.

Buliminidae (VIII) are absent at 53 meters, but with increasing depth they appear, increase in numbers, and finally predominate at 680 meters.

In summary, in the shallower samples (53 to 228 meters) a few families are present, some of which (VIII and XII) are numerous. With increase in depth (309 to 469 meters), there is an increase in the number of families, but none of them is represented by great numbers. On the contrary, the deepest sample (680 meters) again shows great predominance of one family (Buliminidae — VIII) over the others.

Text-figure 2: Foraminifera from the northern Apennines, ranging from upper Miocene to middle Pliocene in age, have been considered. From the Castell'Arquato (Piacenza) section, four samples, nos. 4, 10, 16, and 18, were collected from the bottom to the top of a stratigraphic sequence outcropping near Lugagnano and Castell'Arquato. The lithologic sequence is represented by uniform, blue, massive marly clay of the so-called "facies Piacenziana." The lowest sample, no. 4, was collected from clayey marls near the village of Vernasca in the same area. The age of the samples ranges from lower Pliocene (no. 4) to middle Pliocene (no. 18). The percentages of planktonic and benthonic specimens are from di Napoli (1952). Quantitative data relating to benthonic families are also reported below.

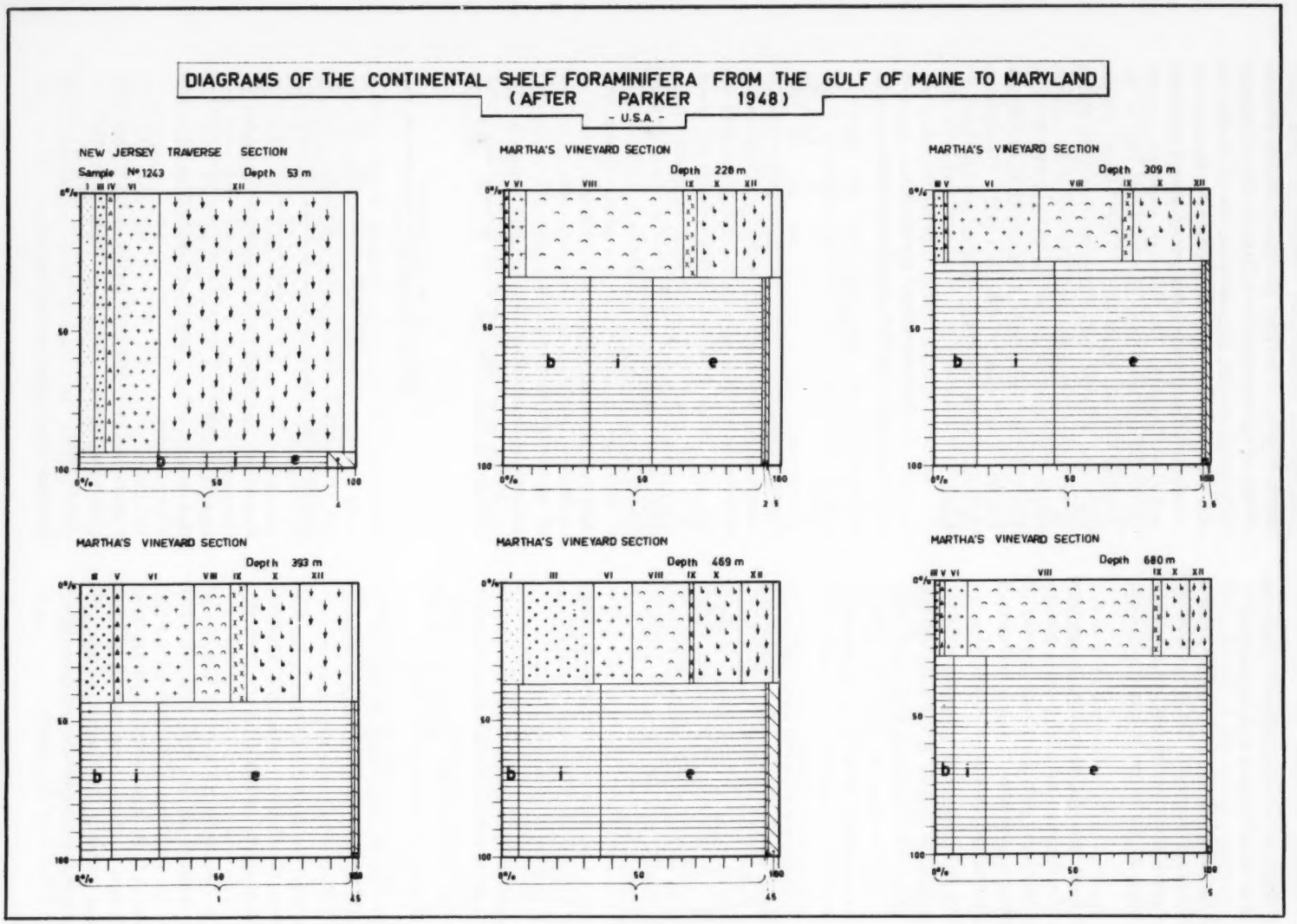
PERCENTAGES OF INDIVIDUALS PER PLANKTONIC GENUS AND SPECIES

Sample no.	4	10	16	18
Genera:	%	%	%	%
Globigerina	69	72	90	100
Globigerinoides	24	25	7	–
Globigerinella	1	–	–	–
Orbulina	3	3	0.4	–
Species:				
Globigerina bulloides d'Orbigny	69	72	87	99
Globigerina (uncertain species)	–	–	3	1
Globigerinoides adriaticus (Fornasini)	4	–	–	–
Globigerinoides conglobatus (Brady)	–	6	–	–
Globigerinoides trilobus (Reuss)	20	18	7	–
Globigerinella aequilateralis (Brady)	1	–	–	–
Orbulina universa d'Orbigny	3	3	0.4	–

PERCENTAGES OF INDIVIDUALS PER BENTHONIC FAMILY

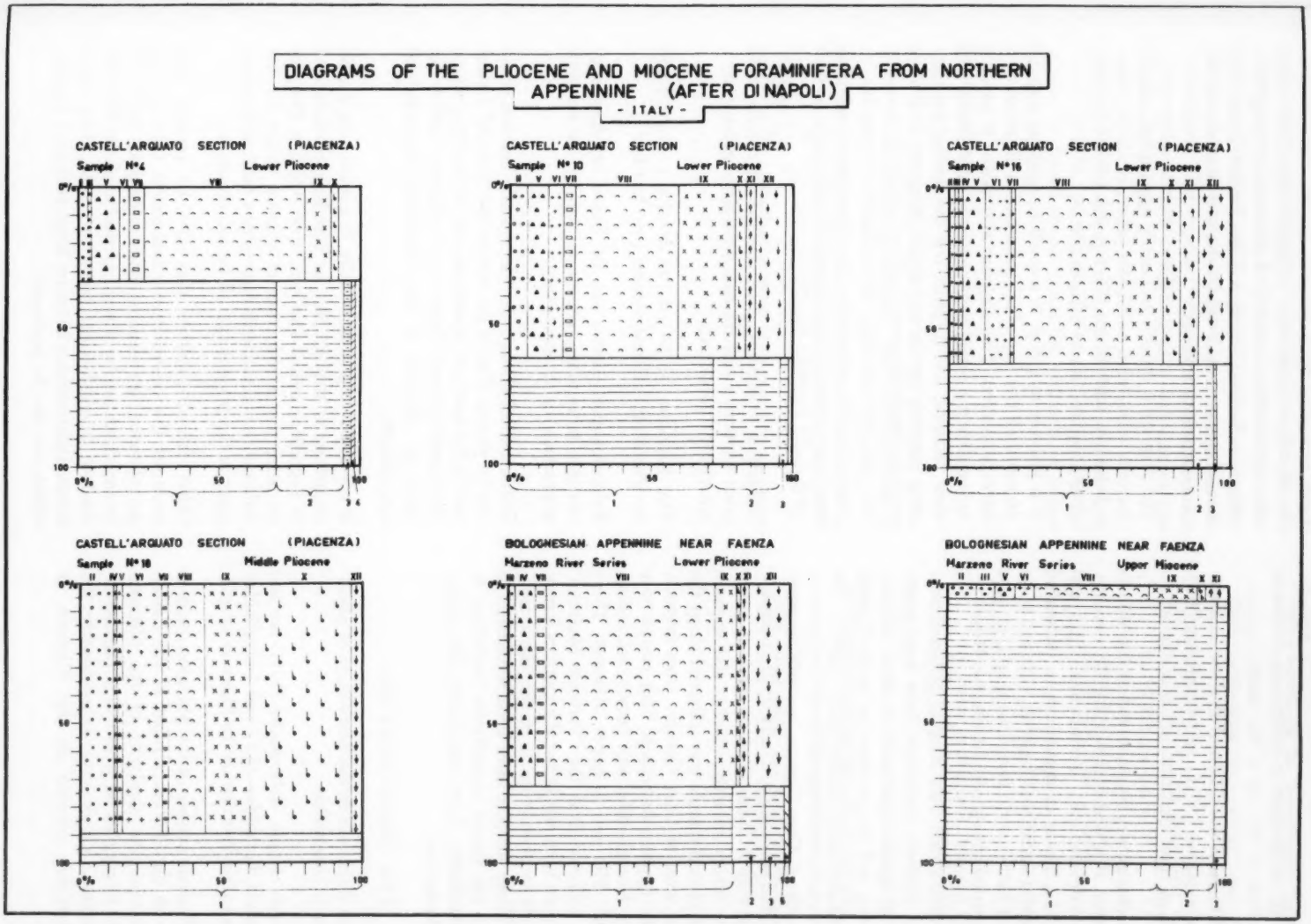
Sample no.	4	10	16	18
	%	%	%	%
Textulariidae	2.3	5.6	1.7	12.0
Valvulinidae	1.0	–	1.5	0.6
Miliolidae	0.5	–	1.5	0.8
Lagenidae	10.0	7.4	8.5	1.8
Nonionidae	3.5	5.6	9.0	14.0
Heterohelicidae	5.0	3.7	1.7	1.8
Buliminidae	57.0	37.0	38.5	13.0
Ellipsoidinidae	1.0	–	–	–
Rotaliidae	9.0	20.0	14.0	16.0
Cassidulinidae	–	3.7	6.0	36.0
Chilostomellidae	2.3	3.7	7.0	–
Anomalinidae	–	11.0	11.0	38.0

The percentage values are approximate.



TEXT-FIGURE 1

I: Rhizamminidae; II: Textulariidae; III: Valvulinidae; IV: Miliolidae; V: Lagenidae; VI: Nonionidae; VII: Heterohelicidae; VIII: Buliminidae; IX: Rotaliidae; X: Cassidulinidae; XI: Chilostomellidae; XII: Anomalinidae; 1: *Globigerina;* 2: *Globigerinoides;* 3: *Orbulina;* 4: *Globigerinella;* 5: *Globorotalia; b: Globigerina bulloides* d'Orbigny; *e: Globigerina eggeri* Rhumbler; *i: Globigerina inflata* d'Orbigny.


DIAGRAMS OF THE PLIOCENE AND MIOCENE FORAMINIFERA FROM NORTHERN APPENNINE (AFTER DI NAPOLI)
- ITALY -
CASTELL'ARQUATO SECTION (PIACENZA)
Sample N°4 Lower Pliocene
CASTELL'ARQUATO SECTION (PIACENZA)
Sample N° 10 Lower Pliocene
CASTELL'ARQUATO SECTION (PIACENZA)
Sample N°16 Lower Pliocene
CASTELL'ARQUATO SECTION (PIACENZA)
Sample N° 18 Middle Pliocene
BOLOGNESIAN APPENNINE NEAR FAENZA
Marzeno River Series Lower Pliocene
BOLOGNESIAN APPENNINE NEAR FAENZA
Marzeno River Series Upper Miocene

TEXT-FIGURE 2

I: Rhizamminidae; II: Textulariidae; III: Valvulinidae; IV: Miliolidae; V: Lagenidae; VI: Nonionidae; VII: Heterohelicidae; VIII: Buliminidae; IX: Rotaliidae; X: Cassidulinidae; XI: Chilostomellidae; XII: Anomalinidae; 1: *Globigerina;* 2: *Globigerinoides;* 3: *Orbulina;* 4: *Globigerinella;* 5: *Globorotalia; b: Globigerina bulloides* d'Orbigny; *e: Globigerina eggeri* Rhumbler; *i: Globigerina inflata* d'Orbigny. The samples from the Castell'Arquato section, nos. 4, 10, 16, 18, are arranged according to their stratigraphic order, from bottom to top.

An examination of the diagrams shows that:

The percentage of planktonic individuals decreases from the bottom to the top of the series.

Diagrams of samples no. 4, 10 and 16 show an abundance of Buliminidae (VIII) and Rotaliidae (IX). The patterns of these diagrams are very similar.

A remarkable change can be observed in the uppermost sample (no. 18), which shows a great development of Cassidulinidae (X), Textulariidae (II) and Nonionidae (VI). These changes may be connected with chronological variations; however, it is not to be discounted that bathymetric variations might, at least in part, have caused changes in the foraminifera.

Torrente Marzeno series: Two samples collected near Faenza, in the northern Apennines, have been examined. The list of species contained in these samples, their frequencies, and observations on environmental conditions were discussed by di Napoli (1951). The first sample was collected west of Torre di Ceparano, 200 meters north of Casa Gessina, on the Marzeno River. The sample consisted of blue-grayish, compact, massive marly clay ("facies Piacenziana," of lower Pliocene age), which directly overlies the gypsum formation. The second sample was collected along the Marzeno River west of Casa Gessina, from immediately below the gypsum formation. This sample was represented by blue-greenish and brown, micaceous, laminated marl. The age is upper Miocene. These samples were collected from the "Torrente Marzeno" series. The sample from just below the gypsum formation corresponds to sample no. 3 of the above-mentioned series. These samples have been considered in order to show the faunal quantitative variations in sediments immediately above and below the evaporitic gypsum formation.

An inspection of the diagrams shows that:

A remarkable difference in the percentage of planktonic species is observable.

In the Miocene sample, Buliminidae (VIII) are less abundant, while Rotaliidae (IX) and Valvulinidae (III) are more abundant than in the Pliocene sample.

When the Pliocene sample of the Marzeno series is compared with the Pliocene samples of the Castell'Arquato section, the similarity of the Marzeno series sample to samples no. 4 and 10 of the Castell'Arquato section, which have approximately the same stratigraphic position in the Pliocene, is evident.

ADVANTAGES OF THE NEW TYPE OF DIAGRAM

In the first place, the examples described above demonstrate the possibility of successfully using these diagrams for both living and fossil microfaunas. The advantages of routine use of the new diagram can be summarized as follows:

The diagram is quickly and easily constructed, requiring only cross-ruled millimeter paper, or simply cross-ruled paper, without need for a protractor and dividers, as are required for circular diagrams.

It is possible to group, in a small area and in a single diagram, all the important quantitative elements of a micropopulation. This diagram also makes it possible to visualize the actual composition of microfaunas and their patterns, and to point out the mutual relationships between the various faunal elements. It is more complete than other diagrams because, as shown in the examples (text-fig. 1), it makes it possible to observe at the same time the quantitative relations between planktonic and benthonic individuals, as well as between families, genera and species.

Numerical frequency data, instead of merely their areal relations (as is the case with circular diagrams), are visually presented.

The diagrams can be used to develop ecological and environmental reconstructions (see text-fig. 1).

Paleontological zones can be based on frequency changes in families, genera or species, or on their appearance or disappearance.

Chronological changes in lithologically uniform strata can be shown. This is the case in the "Scaglia" formation in the northern Apennines and in the Alps, where the transition from Cretaceous to Eocene beds is defined by changes in the planktonic foraminiferal assemblages.

It is possible to present visually, in a small area, faunal sequences in stratigraphic or bore-hole sections, and to superpose faunal logs one upon another. For this purpose, the introduction of various colors for the different faunal elements represents a marked improvement in the presentation of faunal variations.

Other faunal elements may also be plotted. For example, the quantitative relationships between the porcellanous, arenaceous, and calcareous forms of foraminifera can be shown, as well as those between shallow, brackish-water forms and cold, deep-water forms. Relationships between large and small foraminifera can also be portrayed.

The diagram can be used for other groups of mega- and micro-organisms. For example, the quantitative relationships between Radiolaria, foraminifera, ostracodes and diatoms might well be plotted. As for megafossils, the quantitative relationships between Lamellibranchiata (Pelecypoda) and Gastropoda, and the frequencies of their families, genera and species, can be readily shown.

A microfaunal file can be established, arranged in chronological, ecological, facies, or environmental order, or based simply upon the criterion of microfaunal similarity.

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ABSTRACT: *Two species of the foraminiferal genus* Schackoina, *one of which is new, are described from a marl outcropping near Serramazzoni in the northern Apennines. The age of the beds is believed to be Upper Cretaceous, probably upper Senonian. Stratigraphic variability in the genus* Schackoina *is discussed, and a stratigraphically arranged table showing variation in the diagnostic characters of all known species of* Schackoina *is presented.*

Schackoina from the Upper Cretaceous of the northern Apennines, Italy

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INTRODUCTION

In a preliminary note, the writer (1954) published the discovery of a microfauna with *Gümbelina, Gümbelitria,* and *Schackoina* in a marl bed of the formation *"a Helminthoidea labyrinthica e fucoidi"* in the northern Apennines, near Modena, Italy. The locality is 2 km. north of Serramazzoni, on the right side of National Highway No. 12, between Modena and Abetone Pass. It is an extensive outcrop, about 12 km. in length, of interbedded sandstone, chalk, marl, clay, and limestone. It is underlain and surrounded by a chaotic complex of clays ("argille scagliose") and lesser amounts of basic and ultrabasic rocks (serpentine, diabase), sandstone, limestone (the Tuscan "palombino"), etc., in blocks of varying size. According to modern geotectonic views (Merla, 1952), all of this complex, which is very extensive in the northern Apennines, represents an allochthonous formation which was thrust from the Tyrrhenian area to the present Po Valley, that is, in an east-northeasterly direction. Setting aside for the present all discussion of this as yet unsettled geotectonic problem, it is a fact that paleontologic data on this formation are extremely scarce because of the absence of macrofossils and the difficulty of finding foraminiferal microfaunas.

The outcrop at Serramazzoni, like many analogous large outcrops in the region of the Emilian Apennines, is indicated as "Eocene" on the Carta Geologica d'Italia, F. 96. The discovery of a distinctly Upper Cretaceous microfauna now eliminates any doubt as to the age of these strata with *Helminthoidea labyrinthica* and fucoids. Analogous results were obtained by the writer some years ago (1945, 1947) in some nearby localities of ophiolitiferous clay.

As the complete microfauna will require considerable time for description, it seems advisable to discuss in advance certain important forms. The present paper is therefore concerned only with the species of the distinctive Upper Cretaceous genus *Schackoina* found in this microfauna.

A grant from the Italian National Research Council and a Fulbright travel award made possible the present research studies in micropaleontology in the United States, chiefly in the U. S. National Museum, Washington, D. C. The writer wishes to thank both Dr. Alfred R. Loeblich, Jr., and Dr. Helen Tappan Loeblich of the U. S. National Museum for their assistance during her stay in Washington, and for the research facilities supplied at the U. S. National Museum during the preparation of this study. Dr. Helen Tappan Loeblich also aided by reading the present manuscript and by making various suggestions. The writer also wishes to acknowledge the assistance of Dr. Brooks F. Ellis and Miss Angelina R. Messina of the American Museum of Natural History, New York, in planning the present trip, and their hospitality during her two-week stay in New York. The illustrations on the table and plate were prepared by Lawrence Isham, Scientific Illustrator, U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

Family HANTKENINIDAE

Genus SCHACKOINA Thalmann, 1932

Schackoina trituberculata (Morrow)
Plate 1, figure 11

Hantkenina trituberculata MORROW, 1934, Jour. Pal., vol. 8, no. 2, p. 195, pl. 29, figs. 24, 26-28.
Schackoina trituberculata (Morrow). — LOETTERLE, 1937, Nebraska, Geol. Survey, Bull., ser. 2, no. 12, p. 47, pl. 7, fig. 7a-b.
Schackoina trituberculata (Morrow). — CUSHMAN, 1946, U. S. Geol. Survey, Prof. Papers, no. 206, p. 148, pl. 61, figs. 13-16.

Available material: Two specimens, one of them well preserved, but with tubulospines broken. (The term "tubulospine" is here proposed for spine-like extensions of the chambers, as found in *Schackoina*, which are hollow and are connected internally with the chamber cavity and are not solid as are true spines.)

Description: The first whorl consists of three or four trochoid chambers. The final whorl always has three chambers, the two latest shaped like an elongate flask. The final chamber is always much better developed than the others. Tubulospines originate by an abrupt constriction of the outer chamber wall, so that they are narrow from their base. Because of this constriction, this species shows neither the polyhedral chamber outline nor the large tubulospine bases that are characteristic of *Schackoina multispinata* (Cushman and Wickenden). The aperture is at the base of the final chamber.

Horizon and locality: Figured hypotype and unfigured hypotype from the Upper Cretaceous, "marne a fucoidi," 2 km. north of Serramazzoni, on the right side of National Highway No. 12, between Modena and Abetone Pass, northern Apennines, Italy.

Stratigraphic distribution: Coniacian-Santonian; originally described from the Niobrara formation, Smoky Hills member, Nebraska.

Depository: Laboratory of Micropaleontology, Institute of Geology, University of Modena, Italy.

Discussion: The Italian specimens agree fully with the characters indicated by Morrow, by Loetterle, and by Cushman, except for a greater difference in size between the final chamber and the other coronal chambers. However, the small number of specimens available prevents determination of the degree of variability of chamber size within the species or the relative importance of this character.

Schackoina tappanae
Montanaro Gallitelli, new species
Plate 1, figures 1-10

Available material: About thirty specimens, generally well preserved, tubulospines broken.

Description: Test slightly trochoid, biumbilicate. Chambers six or seven, in two nearly planispiral whorls, the first whorl rarely visible. Final whorl consists of three flask-shaped chambers, planispirally arranged in all the specimens observed. Sutures very deeply depressed. The three latest chambers are always very unequal in size. All tubulospines radially disposed in the plane of coiling and rather narrow from their base. Very rarely a short radial tubulospine occurs in the latest chamber of the first whorl. Aperture arcuate, at the base of the final chamber, with a strong lip extending laterally nearly to the umbilicus.

The thickness of the test is variable, as shown by examination in castor oil at a magnification of 400 times. The surface may be roughened, rarely very finely hispid. The first whorl is more or less visible depending upon the thickness of the test.

Dimensions: Greatest diameter of holotype 0.21 mm.; least diameter 0.18 mm. Paratypes range from 0.13 to 0.23 mm. in maximum diameter.

Horizon and locality: Upper Cretaceous (probably upper Senonian), "marne a fucoidi," 2 km. north of Serramazzoni, on the right side of National Highway No. 12, between Modena and Abetone Pass, northern Apennines, Italy.

Depository: Holotype and figured paratypes deposited in the Laboratory of Micropaleontology, Institute of Geology, University of Modena, Italy. Unfigured paratypes deposited in the U. S. National Museum, Washington, D. C.

Discussion: A comparison of *Schackoina tappanae* with all the known species of *Schackoina* follows:

Sigal (1952) described and figured a new species, *Schackoina cabri*, from a doubtful Aptian horizon in Tunisia (Dj. Rhazouane). He attributed to the same species, with much doubt, a poorly preserved specimen from the upper Barremian of Dj. Djaffa. The description is as follows: "Absolument caractéristique par le nombre de loges à deux épines et l'irrégularité de ces épines, ainsi que par le nombre de loges au dernier tour, tous caractères qui le différencient de *S. moliniensis* Reichel."

This brief description indicates neither the number of chambers with two tubulospines, nor the type of

"irregularity" of the spines — whether of position or shape. The two figures, dorsal side and profile, show the stocky shape of the test, the less inflated chambers and the large tubulospine bases, a total of thirteen chambers in two whorls, the final whorl with five chambers (possibly six, as the figure is not clear). In the figure, double spines are visible only in the two latest chambers, and they appear disposed perpendicularly to the final plane of coiling. However, leaving aside any discussion of either the stratigraphic position or the relationship between Sigal's species and *Schackoina moliniensis* Reichel, it is certain, even with this scanty information, that Sigal's species is quite distinct from the species from Serramazzoni.

Schackoina primitiva Tappan, from the lower Cenomanian Grayson formation of Texas, has three chambers in the final whorl, but the chambers are less inflated, the sutures are slightly depressed but not strongly constricted, and the periphery is only very slightly lobulate (Tappan, 1940, p. 123). This peripheral character is highly diagnostic.

Schackoina cenomana (Schacko) from the Cenomanian of Moltzow, Mecklenburg, and Hirschgarten near Berlin, has four or five chambers in the final whorl instead of three, as in *Schackoina tappanae*. *Schackoina multispinata* (Cushman and Wickenden), from the Coniacian-Santonian Austin chalk and the Campanian Pecan Gap chalk of Texas, is quite different from *Schackoina tappanae* because of the polyhedral form of the multitubulospinate chamber. *Schackoina trituberculata* (Morrow), from the Coniacian-Santonian Smoky Hills member of the upper part of the Niobrara formation of Nebraska, also generally has three tubulospines on the final chamber.

Schackoina gandolfii Reichel, from the Cenomanian of the Breggia region, Canton Ticino, and Gubbio, in the central Apennines, is easily distinguishable by the presence of two tubulospines on the final chamber, which are disposed in a plane perpendicular to that of coiling. I have not been able to compare my specimens with *Schackoina senoniensis* (Thalmann), from the upper Senonian Pattenauer marl (Campanian; see Aurouze and de Klasz, 1954) of the Bavarian Alps. The only figure of this species, which is so important stratigraphically, was given by Egger (1900) under the name of *Siderolina cenomana* Schacko. In 1932, Thalmann separated Egger's form as a new species, *Hantkenina (Schackoina) senoniensis*, but did not give any figures. In any case, the figure given by Egger (1900, pl. 21, fig. 42) represents a specimen with four less discrete chambers, and the description also indicates a variability of from three to five chambers in the final whorl.

Egger's type collection was destroyed during World War II. De Klasz (Aurouze and de Klasz, 1954) did not collect samples from the type locality of Pattenau, but in the upper Campanian marl of Disselbach, east of Grub, on the Traun River, near Eisenärzt, he discovered specimens supposedly corresponding to Egger's species, and attributed them with doubt to *Hastigerinella (Hastigerinoides) rohri* Bronnimann. Because of the difference in the two localities, we cannot determine the identity of Egger's (and Thalmann's) species.

Consequently, considering the elements of specific value generally accepted by the majority of workers on this genus, the concurrence of the following characters can be indicated as diagnostic for the new species *Schackoina tappanae:* (1) three coronal chambers; (2) one tubulospine per chamber, radially arranged and in the same plane; (3) a considerable difference in size between the final chamber and the others in the final whorl.

The new species is named in honor of Dr. Helen Tappan Loeblich, in recognition of her work on Cretaceous foraminifera.

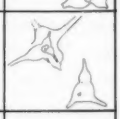
STRATIGRAPHIC VARIABILITY IN THE GENUS SCHACKOINA

A discussion of *Schackoina* was given by Reichel (1948, p. 408). Chiefly on the basis of his study of the peculiar species of the Breggia (he did not cite *Schackoina primitiva,* which was at that time the oldest species known), he attempted to work out a series of evolutionary stages for this genus.

Schackoina cabri Sigal (1952) is indicated from the Aptian of Djebel Rhazouane in Tunisia. However, the stratigraphic position of this horizon is not yet well established in that region, as Sigal notes (p. 20): "Sous tous les faciès c'est, pour l'instant, l'étage le moins bien caractérisée; aussi n'en pourrons-nous dire que peu de choses. Car l'un des foraminifères les plus repandus, *Orbitolina conoidea-discoidea,* . . . n'est pas caractéristique de l'étage puisque, apparu sans doute dès le sommet du Barrémien, il existe peut-être encore à la base du Cénomanien." Sigal adds that he also found "un mauvais moule qui semble devoir être rapporté à cette espèce" in the upper Barremian of Dj. Djaffa. Additional well-preserved and recognizable material must be obtained in order to confirm this interesting, stratigraphically lowest occurrence of *Schackoina.*

Schackoina primitiva Tappan is from the lower Cenomanian of Texas. (The chronological attribution of *Schackoina primitiva* is here correct, as the Grayson formation is now considered to be Cenomanian instead of Albian, as previously indicated.) The upper

TABLE 1. STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF THE GENUS SCHACKOINA

		Species of Schackoina	Locality	Coiling: p=planispiral t=trochoid	no. of chambers in final whorl	no. of tubulospines in final chamber	orientation of tubulospines in relation to plane of coiling	maximum diameter in mm. at base of tubulospines	
MAESTRICHTIAN		S. multispinata	Caucasus Gan, Pyrenees Boucheck, Upper Bavaria El Alca, Bizerte, Tunisia	P	3	5	irreg.	?	
SENONIAN	CAMPANIAN	S. multispinata	Taylor marl, Pecan Gap mbr. Rockwall County, Texas	p	3	5	irreg.	0.24	
	CONIACIAN-SANTONIAN	S. tappanae	Serramazzoni marl, N. Apennines, Italy	t	3	1	complan.		
		S. trituberculata	Smoky Hills mbr.(Niobrara) Nebraska	p	3-4	1-3	irreg.	0.75	
			Serramazzoni marl, N. Apennines, Italy	?		3	irreg.		
		S. senoniensis	Disselbach, Pattenauermergel, Bavaria	P	3-5	1	complan.	0.12-0.16	
		S. multispinata	L. Austin chalk, Grayson Co., Texas	p	3	5	irreg.	0.24	
TURONIAN		S. jeanneti	Tour d' Ai, Entre-deux-sex, France	?p	3	2	axial	0.24	
		S. trituberculata	Greenhorn formation, Kansas	p	3-4	1-3	axial	?	
CENOMANIAN		S. cenomana bicornis	Salies-de-Bearn, Aquitaine, France	p	4	2	axial	?	
		S. gandolfii	Salies-de-Bearn, Aquitaine, France	p	4-5	1	complan.	?	
		S. moliniensis	Salies-de-Bearn, Aquitaine, France	?	4	2	axial	?	
		S. pentagonalis aperta	Breggia, "Scaglia variegata", Canton Ticino, Switzerland	?	4	?1		0.20-0.24	
		S. moliniensis	Breggia, "Scaglia rossa", Canton Ticino, Switzerland	?	4	2	axial	0.17-0.21	
		S. gandolfii	Breggia, "Scaglia rossa", Canton Ticino, Switzerland; Gubbio, "Scaglia", Apennines, Italy	p	4-5	1	complan.	0.19-0.21	
		S. cenomana	Maltzow, Mecklenburg, Germany; Bohrloch-Hirschgarten, Berlin, Germany	t	4-5	1	complan.	0.19-0.21	
		S. pentagonalis	Breggia, "Scaglia variegata" (lower part) Canton Ticino, Switzerland	t	5	1	complan.	0.19	
		S. cenomana bicornis	Breggia, "Scaglia rossa", Canton Ticino, Switzerland; Gubbio, "Scaglia", Apennines, Italy	p	4	2	axial	0.19	
		S. primitiva	Grayson formation, Washita Group, Texas	t	3	1	complan.	0.17	
ALBIAN									
? APTIAN		S. cabri	Dj. Rhazouane, Tunisia	?t	6	?2	?axial	0.30	

limit of the genus, so far as now known, was in the Campanian (upper Pecan Gap chalk, Texas), with the long-ranging form *Schackoina multispinata* (Cushman and Wickenden), which also occurs at the base of the Coniacian, in the lower part of the Austin chalk.

In the Breggia beds, where *Schackoina* is present at fourteen horizons in a 140-meter section, Reichel found a gradual passage from forms with five chambers in the coronal whorl to forms with three chambers in the coronal whorl, with an increase in the number of tubulospines and their consequent displacement from the plane of the whorl. Reichel assumed, in other words, that the following characters are stratigraphically variable: (1) a progressive reduction in the number of coronal chambers; (2) an increase in the number of tubulospines in the final chamber; (3) when more than one tubulospine is present, they assume an orientation perpendicular to the plane of the whorl, or at least an irregular position.

In Table 1 the data are shown for all species hitherto described, with regard to the characters considered stratigraphically diagnostic by Reichel. The table shows that Reichel (1948, p. 406) was quite correct in his statement that our knowledge of this important population is as yet quite incomplete. As concerns Reichel's point 1 (progressive reduction in the number of coronal chambers), the lower Cenomanian species *Schackoina primitiva* has only three coronal chambers. We may also observe, in relation to points 2 and 3, that this same early species already presents an asymmetrical tubulospine, the first one formed in the test, and that *Schackoina cabri* Sigal shows multiple asymmetrical tubulospines, at least in the two latest chambers.

The microfauna of Serramazzoni seems to indicate an upper Senonian age. *Schackoina tappanae* and *Schackoina trituberculata* can therefore be considered among the stratigraphically youngest forms of *Schackoina*. It is interesting that *Schackoina tappanae* also shows an inversion in the stratigraphic sequence of characters indicated by Reichel; in other words, this species has only one tubulospine per chamber in the final whorl, accompanied by a reduction in the number of coronal chambers, which is never more than three.

This fluctuation of characters is well shown in Table 1. Not even the size can be considered of any stratigraphic value. *Schackoina primitiva* is 0.19 mm. in maximum diameter, and in general there seems to be an increase in size with later stratigraphic occurrence. However, *Schackoina senoniensis*, which was indicated as having a maximum diameter of 0.12-0.16 mm., appears in the Senonian. Unfortunately, the type of this interesting species from the Bavarian Upper Cretaceous is no longer available.

There is only a single character that still appears to be of value, namely, the progressive disjunction of the coronal chambers. The two extremes of this development are shown in *Schackoina primitiva* and *Schackoina jeanneti* Reichel. A statistical examination of the ratio between the diameter of the first chamber (proloculus) and the diameter of the final chamber, measured from the suture to the base of the tubulospine, is suggested, as well as of the ratio between the diameters of the largest and smallest coronal chambers, giving the rate of increase in chamber size. Our studies have actually shown that there was a progressive increase in the size ratio and in the degree of disjunction of the coronal chambers, rather than an absolute reduction in the number of coronal chambers. *Schackoina primitiva* and *Schackoina multispinata* are considered to be the extremes of this evolutionary series.

Just as this study was ready for publication, the recent paper by Aurouze and de Klasz (1954), with a discussion of the genus *Schackoina*, came to the attention of the writer. Additional references which they gave concerning the stratigraphic and geographic distribution of some of Reichel's species were then added to our Table 1. There seems to be no further necessity, however, to emend the present text.

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EXPLANATION OF PLATE 1

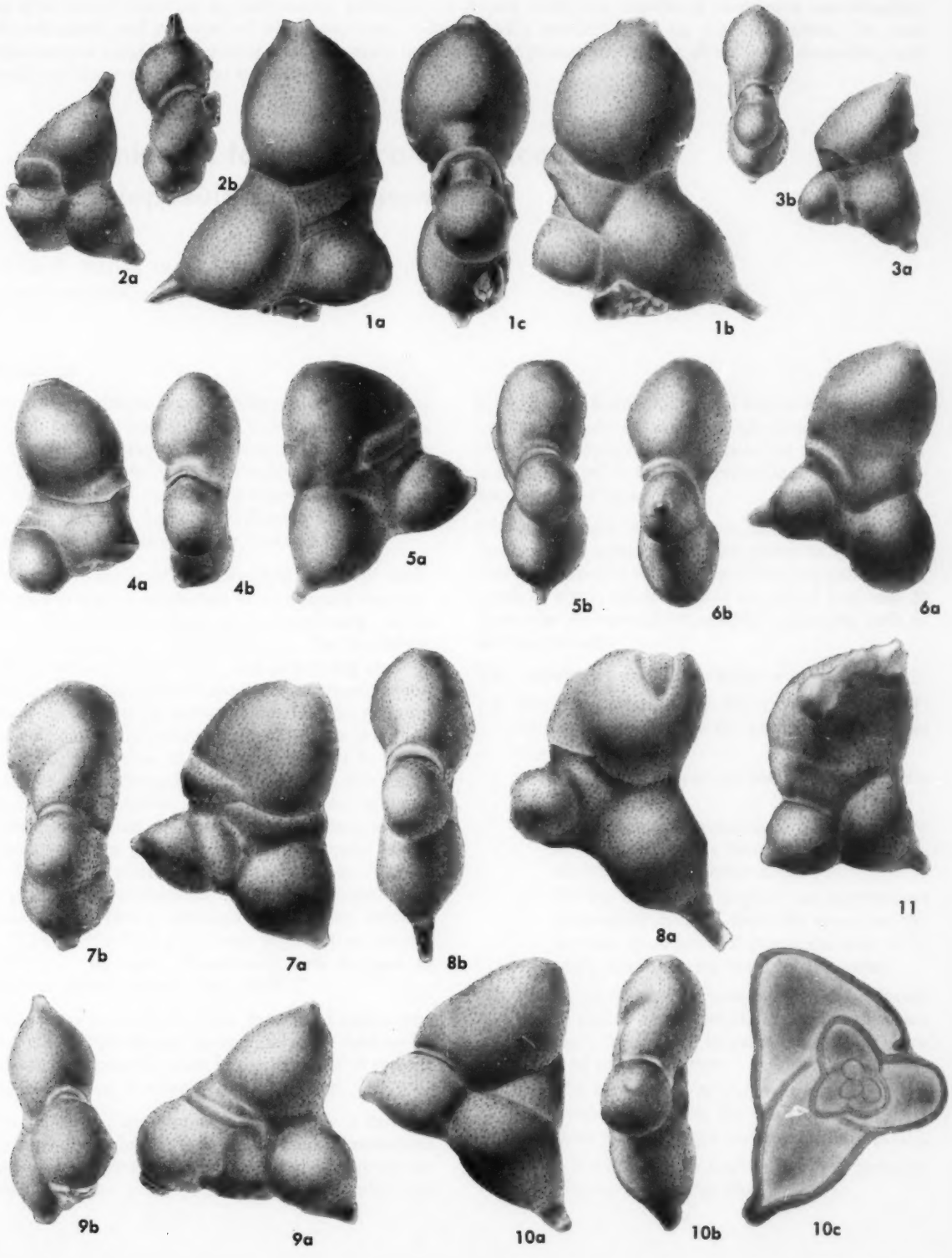
All figures × 325. All specimens from the Upper Cretaceous (probably upper Senonian) near Serramazzoni, northern Apennines, Italy. All figured specimens deposited in the Laboratory of Micropaleontology, Institute of Geology, University of Modena, Italy.

1–10 *Schackoina tappanae* Montanaro Gallitelli, n. sp.

1, holotype: a-b, opposite sides; c, edge view. 2-10, paratypes: a, side views; b, edge views; 10c, view in transmitted light, to show early coiling.

11 *Schackoina trituberculata* (Morrow)

Side view of hypotype.


2a
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ABSTRACT: *Tests of planktonic foraminifera are clastic particles from an off-shore source area, shoreward deposition of which is controlled by sedimentary processes. In Recent sediments, significant correlation was observed between depth and per cent of planktonic tests. Islands had a marked effect on the distribution. In fossil sediments, the varying per cent of tests may assist in locating the former strand line, direction of deepening, and possible off-shore topographic anomalies.*

Planktonic foraminifera as indicators of depositional environment

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INTRODUCTION

One of the problems in paleontology is the reconstruction of past environments of deposition. In micropaleontology, an important approach to this problem has been the study of living benthonic foraminifera, on the assumption that the life zones of forms in the geologic past may be inferred from a knowledge of the preferred habitat of similar Recent forms.

The use of living benthonic foraminifera for the establishment of typical depth-zone assemblages is exemplified by Phleger and Parker's monumental work (1951) on the ecology of foraminifera in the northwest Gulf of Mexico. In that work, the underlying assumptions are biologic. Different species of benthonic foraminifera are typical of certain habitats. The majority of their tests are not transported far from the preferred life zone. Sediments can be recognized as to depth zone by the contained tests of different species of benthonic foraminifera. Planktonic species are not, in themselves, characteristic of any depth zone, as their habitat in life is principally the upper layers of the off-shore water masses. Consequently, no use is made of planktonic foraminifera in the determination of faunal depth facies, although the authors mention (p. 67) that "the total population of planktonic foraminifera . . . increases offshore and with increase in depth in most traverses (figs. 26-28)."

While many investigators have mentioned higher percentages of planktonic foraminifera in deep-water sediments, apparently none have attempted to present this information in a formalized statement.

The underlying assumption of this paper is that the per cent of planktonic tests in the total foraminiferal assemblage is closely related to the proximity of unobstructed open water and is principally explainable by inferences based on the end results of sedimentary processes. There are many complications, such as the effects of topography and currents, but the investigator is not obligated to infer the probable life-zone preference of extinct forms.

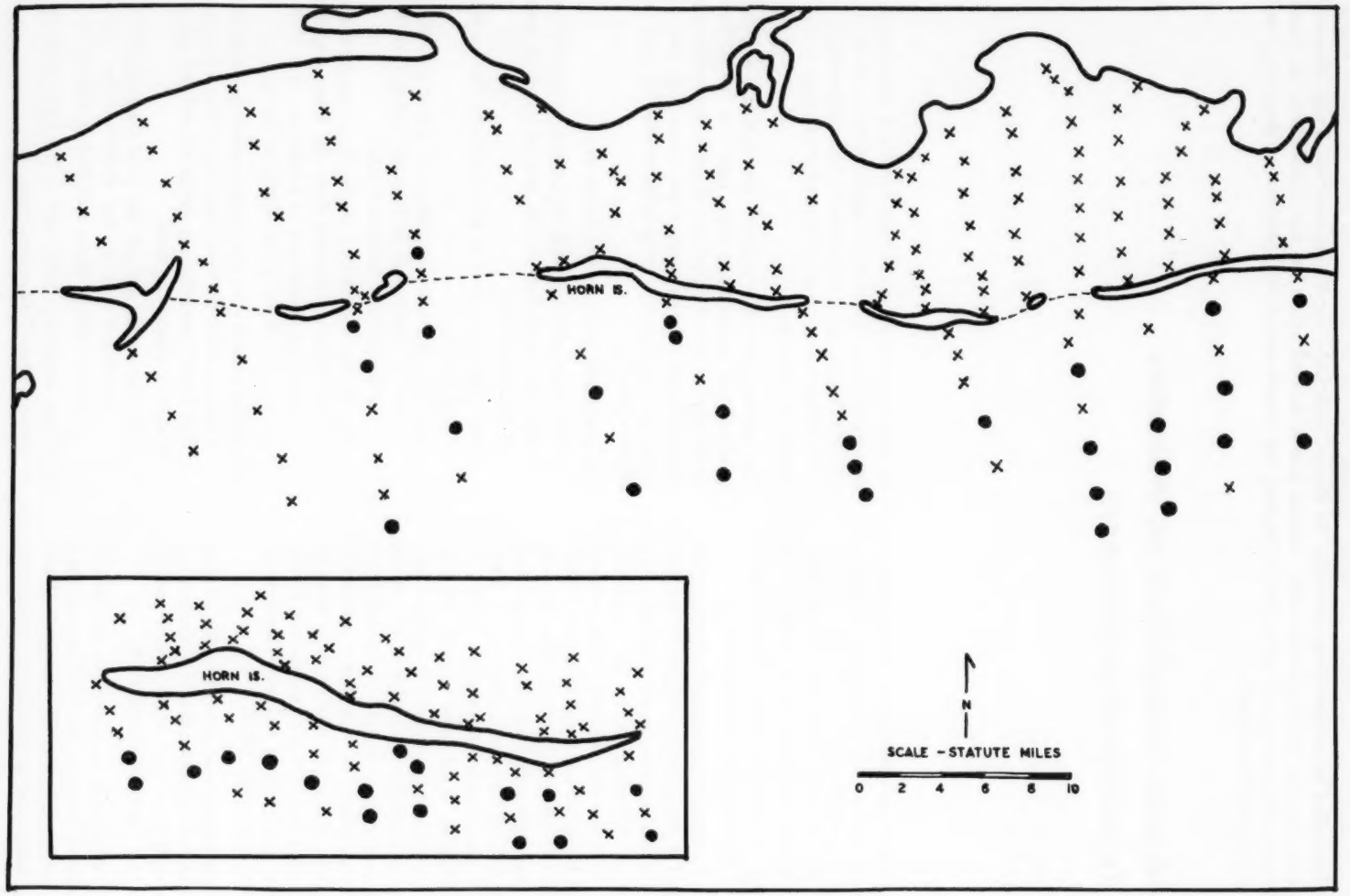
The percentages of planktonic foraminifera in fossil foraminiferal assemblages may prove to be another useful approach to the problem of deducing the former depth of water, the location of the strand line, and, at times, the presence of topographic anomalies, such as offshore islands.

The postulates basic to this paper are:

I. The transportation and deposition of planktonic tests are controlled by the normal physical laws of sedimentation.
   (a) The source area of the planktonic tests is the open sea.
   (b) The absolute abundance of planktonic tests in the sediments is inversely related to the distance from the source area.
   (c) To the extent that depth is an approximate measure of distance from the open sea, the absolute abundance of planktonic tests is directly related to the depth of the water.

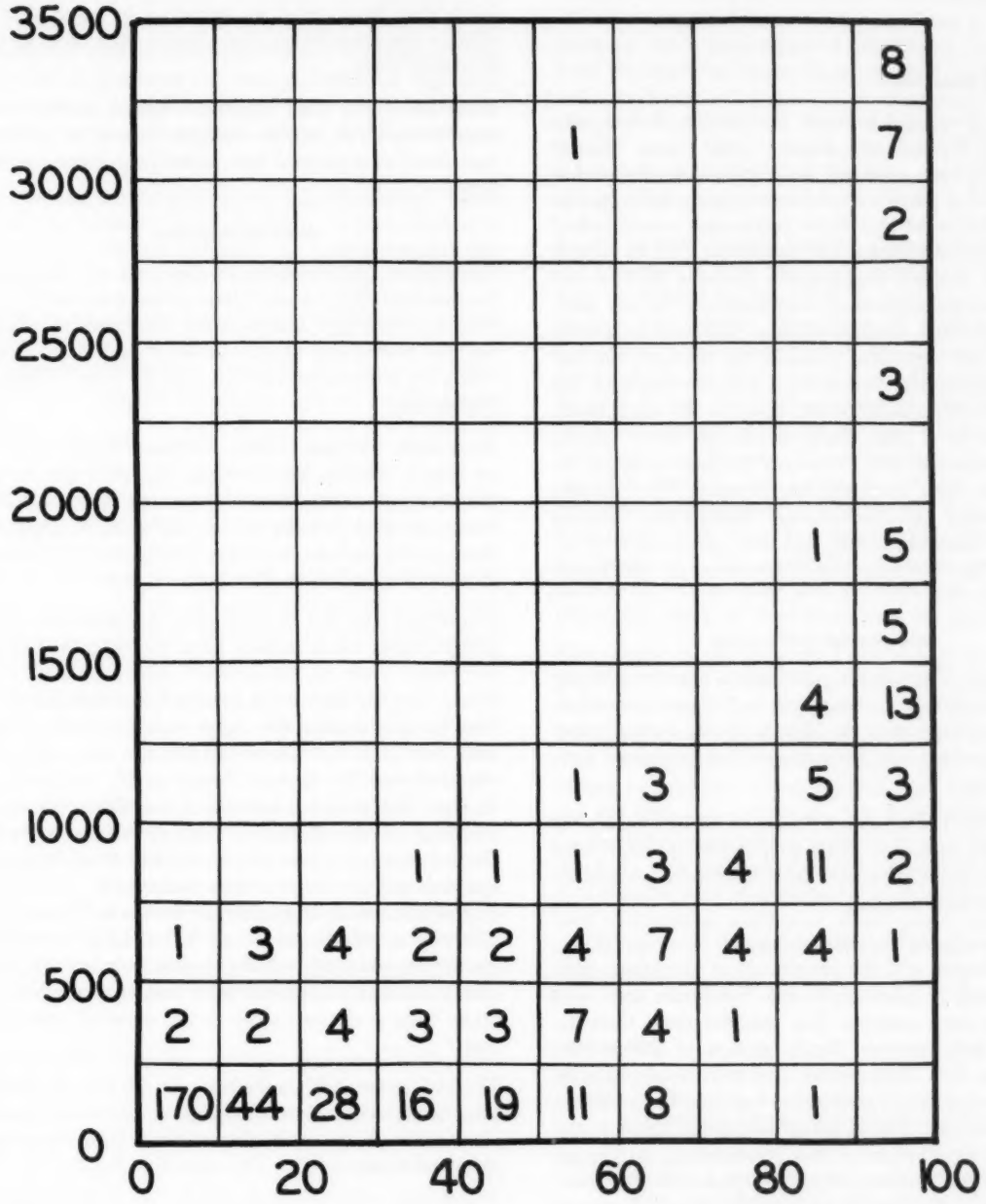
II. Within a local area, the gross number of benthonic tests is sufficiently invariable to provide a reasonable basis from which to judge the relative abundance of planktonic tests.
   (a) The source area of the great majority of the benthonic tests is the shallow-water, nearshore zone (Phleger and Parker, 1951, p. 63).

III. These conditions have held in the past, probably since Upper Cretaceous time.



TEXT-FIGURE 1

Sketch map of the Mississippi Sound area. Crosses indicate location of bottom samples which failed to contain tests of planktonic foraminifera. Dots indicate location of bottom samples which contained tests of planktonic foraminifera. Seventeen stations plotted both on main and on inset map.



TEXT-FIGURE 2

Bivariate scatter diagram showing relationship of per cent of planktonic foraminifera to depth. Ordinate scale: Depth in meters. Abscissal scale: Per cent of planktonic foraminifera.

The deposition of foraminiferal tests is envisaged as a process wherein the interacting sedimentation *from two different source areas* is fundamental in determining the percentage of planktonic forms in a given sample.

STATISTICAL ANALYSES

With the foregoing in mind, the wealth of data contained in Phleger and Parker (1951) and Phleger (1954) has been analyzed statistically for relationship of per cent of planktonic foraminifera to depth and to area, in the belief that these parameters would reflect sedimentary conditions. The northwest Gulf of Mexico region is without topographic features that would cause obvious secondary complications in the sedimentary pattern. Bottom samples from this area were analyzed for degree of relationship between the per cent of planktonic foraminifera and the depth of the water. The Mississippi Sound area, on the other hand, is divided by a loose chain of islands. These islands form a barrier to the shoreward transportation of the planktonic tests from the source area. The samples were divided into two groups, inshore and offshore from the chain of islands, and were analyzed with regard to the incidence of occurrence of planktonic forms.

Northwest Gulf of Mexico area

Hypothesis: There is no relationship between the per cent of planktonic foraminifera in the total foraminiferal assemblage and the depth of the water, other than that which may be expected due to chance sampling errors.

Basic data: Phleger and Parker (1951), Tables 10 through 21, inclusive, which give depth of water, total planktonic population, and total benthonic population for 439 bottom samples.

Procedure: Samples were arranged in order of increasing depth, and the percentage of planktonic tests in the total of planktonic and benthonic tests was noted for each sample. The samples were then assembled into fourteen depth groups of 250 meters each, from 0 to 3500 meters, and were analyzed with regard to degree of relationship between the variables (depth and per cent of planktonic forms) and to the statistical significance of this relationship. As the relationship is curvilinear, the correlation ratio was used. The value of the correlation ratio for the prediction of per cent of planktonic foraminifera in the total foraminiferal assemblage from a knowledge of depth is .855, a high correlation. The value of the correlation ration for the prediction of depth from a knowledge of the per cent of planktonic foraminifera is lower, on the order of .45. However, despite the greater accuracy of prediction in the former case, both correlation ratios are statistically highly significant in the sense that they could be expected to occur due to chance sampling errors alone fewer than once in one thousand times.

Conclusion: The null hypothesis stated above is untenable. In terms of this analysis, it may be assumed that there is a general law underlying these correlations.

Mississippi Sound area

Hypothesis: With regard to per cent of planktonic foraminifera, there is no difference between the foraminiferal assemblage inshore from the chain of islands and the assemblage on the seaward side of the island —i.e., the samples are random samples from a common population.

Basic data: Phleger (1954), bottom samples as noted on map (Phleger, 1954, text-fig. 2), with the exception of thirteen samples on Horn Island proper, which were not used because of the difficulty of assigning them to the inshore or seaward area. Percentage data obtained from Tables 4 through 10, inclusive.

Procedure: The 269 samples were assembled into two groups, those taken inshore from the chain of islands, and those taken on the seaward side (see map, text-fig. 1). Depths were not given for the samples; inshore from the island chain the depth varied from 0 to somewhat over 20 feet, while on the seaward side within the sampled area the bottom sloped gently to depths of 60 feet. This is but a fraction of the 250-meter depth grouping of the northwest Gulf of Mexico samples. Consequently, per cent of planktonic foraminifera was ignored, and the samples were analyzed for occurrence or non-occurrence of planktonic tests. On the seaward side of the islands, 44 out of 107 samples contained planktonic tests, while inshore only 1 out of 162 samples contained planktonic tests, and that sample was taken from a channel close to the seaward area (see map).

The chi square for these data was 75.89; the probability that a chi square this large would occur due to chance sampling errors alone is less than once in a thousand times.

Conclusion: The hypothesis that these are random samples from a common population is untenable. It may be assumed that the chain of islands has had a marked effect on the distribution of the planktonic tests.

DISCUSSION

The correlation between depth and per cent of planktonic foraminifera in the northwest Gulf of Mexico region may be the result of normal sedimentary processes of transportation and deposition at work in an unobstructed area. It is our expectation that a curvilinear relationship between the two variables, as expressed in text-figure 2, will be found to occur on all unobstructed coasts, although the shape of the curve may vary.

The results of the analysis of the Mississippi Sound region populations are considered to be evidence in favor of a marked influence of certain topographic anomalies on the distribution of planktonic tests.

Some features of the depositional environment of fossil sediments may be inferred from the percentages of planktonic tests present, especially if data are available from several control points, or sufficient for the preparation of a biofacies map. Such a map could assist in locating the direction of open water and the former strand line, possible barrier islands and shoals, as well as inferring the probable subsea gradient. In particular, a sharp decrease in percentage between adjoining areas might signify former reefs, or barrier islands. Also, the "reverse" sedimentation of the planktonic tests might prove useful as a check on the correctness of inferences based on the sedimentary pattern of land-derived clastics.

The basic information is easily assembled and cast in graphic form. It is a relatively simple task to pick the planktonic foraminifera from the remaining benthonic forms. The sample is counted for tests of the two groups and is expressed as the per cent of planktonic tests in the total count of planktonic and benthonic tests. If portions are counted, precautions are taken to preserve the random nature of the samples. In poorly preserved material, an estimate of the percentage of planktonic forms may still be possible. The problem of differential destruction, always present in fossil assemblages, must be handled in an objective manner.

The absolute abundance of tests in a given sample depends in part on the masking effect of the clastic material, and the count per sample of sediment may lessen toward the source area of the clastics. However, this should not influence the relative percentages of foraminifera. In fact, if the gross numerical population of benthonic foraminifera is comparable, it may be immaterial whether the area is one of dominantly detrital or carbonate deposition.

Accuracy might be increased by using a mean of several samples from each location. In this connection, it should be noted that the bottom samples reported by Phleger and Parker (1951, p. 36) contained only about 10 cc. of unconsolidated sediment. From a statistical point of view, percentage of planktonic tests in the total foraminiferal assemblage appears preferable to ratios of benthonic genera as a measurable unit per sample. Populations of key benthonic genera are usually small, with more variability in counts and relative percentages, and consequently greater uncertainty of results.

In the present paper, perhaps the weakest point is the assumption that the gross number of benthonic tests is sufficiently invariable to provide a basis for judging the relative abundance of planktonic tests. Conditions exist where bottom life is impossible, but where planktonic forms could live in the upper waters. In such a case, the high per cent of planktonic tests might lead one to postulate offshore conditions when such were not the case. Nevertheless, it does appear probable that in any series of samples containing benthonic and planktonic tests, the per cent of planktonic tests will decrease shoreward. Direction of deepening and the possibility of shoals and barrier islands can be inferred, and a rough idea of the approximate depth of deposition may be obtained.

The results of the suggested percentage method are possibly no more exact than those of the oscillation chart described by Hoppin (1953). However, its simplicity is a point in its favor. Moreover, at this early date, it appears to be more helpful in delineating former topographic features which may now be stratigraphic traps for petroleum. We look forward to the presentation of additional data which may be manipulated by this method, not only from this area, but also from regions of dominantly carbonate sedimentation, continental shelf and slope areas, coasts with upwelling currents, restricted basins, and other environments.

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ABSTRACT: *The authors have found that* Globigerinelloides algeriana *Cushman and ten Dam, described from the Upper Cretaceous, is actually restricted to the Aptian, and shows affinities with* Planulina cheniourensis *Sigal. So far, this species has been found only in Algeria and in Tunisia.*

Sur la répartition stratigraphique de Globigerinelloides algeriana Cushman et ten Dam, 1948

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Au cours de l'étude de différents échantillons de coupes et de sondages de Tunisie, l'un de nous (C. G.) a eu l'occasion de rencontrer un foraminifère qui correspond à l'espèce décrite par Cushman et ten Dam (1948) sous le nom de *Globigerinelloides algeriana*. Ces auteurs la signalent dans le Crétacé supérieur du Djebel Menaouer, qui se situe dans l'Ouest de l'Algérie entre Relizane et Uzés-le-Duc. *Globigerinelloides algeriana* Cushman et ten Dam est très caractéristique par son test planispiralé, légèrement évolute chez les formes adultes, ses loges globuleuses, ses sutures déprimées, radiales, qui deviennent sigmoides pour les dernières loges (voir fig. 1-3).

Elle est nettement apparentée au genre *Globigerinella* Cushman, 1927. Il nous semble que *Globigerinelloides algeriana* Cushman et ten Dam a aussi de nettes affinités avec *Planulina cheniourensis* Sigal, 1952, qui s'en distingue par sa périphérie nettement tranchante, la forme des sutures, les loges plus aplaties et à lèvres ombilicales. Les deux espèces présentent le même nombre de loges, une tendance à devenir évolute, et leur ouverture arquée se place à la base de la face orale. Aucun stade évolutif n'a pu être observé entre ces deux espèces.

En Tunisie, des conditions de gisement favorables nous ont amenés à considérer *G. algeriana* comme ayant une bonne valeur stratigraphique car elle a été trouvée dans un même niveau, en des localités différentes, et accompagnée de macrofaunes. Cette espèce est toujours associée à une microfaune principalement benthonique qui se situe nettement sous les zones à foraminifères pélagiques *(Rotalipora, Thalmanninella, Globotruncana)* du Crétacé moyen et supérieur, qui abondent dans la région où elle a été observée. *Globigerinelloides algeriana* se trouve donc toujours et uniquement dans des niveaux plus anciens que le Cénomanien.

In the course of studying various samples from sections and wells in Tunisia, one of us (C. G.) happened to find a foraminiferan which is identical with the species described by Cushman and ten Dam (1948) as *Globigerinelloides algeriana*. Those authors reported it from the Upper Cretaceous of Djebel Menaouer, which is located in western Algeria between Relizane and Uzés-le-Duc. *Globigerinelloides algeriana* Cushman and ten Dam is very distinctive because of its planispiral test, which is somewhat evolute in the adult form, its globular chambers, and its depressed, radial sutures that become sigmoidal in the last-formed chambers (see figs. 1-3).

The species is evidently related to the genus *Globigerinella* Cushman, 1927. It seems to us that *Globigerinelloides algeriana* is also obviously related to *Planulina cheniourensis* Sigal, 1952, which differs from it in its distinctly acute periphery, the form of its sutures, and in its more flattened chambers which possess umbilical lips. The two species show the same number of chambers, a tendency to become evolute, and an arcuate aperature situated at the base of the apertural face. We have been unable to observe any intermediate stages between these two species, however.

In Tunisia, favorable conditions of deposition have led us to regard *G. algeriana* as having good stratigraphic value, as it has been found in the same horizon at different localities, accompanied by macrofossils. This species is always associated with a microfauna that is predominantly benthonic, which lies distinctly below the zones with pelagic foraminifera *(Rotalipora, Thalmanninella,* and *Globotruncana)* of the Middle and Upper Cretaceous, which are very abundant in the area where the species was found. *Globigerinelloides algeriana* thus occurs always and only in horizons older than the Cenomanian.

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1 2 3

TEXT-FIGURES 1-3

Globigerinelloides algeriana Cushman and ten Dam.
Spécimen tunisien; gisement d'El Ariana (Tunisie).

Globigerinelloides algeriana a été trouvée en différents endroits des environs de Tunis et du Sahel associée à une microfaune à Lagenidae, Anomalinidae, *Gyroidina, Globorotalites* et à *Globigerina* du groupe de *G. infracretacea* Glaessner; cette microfaune se trouve dans toutes les coupes étudiées, sous une microfaune à *Planulina cheniourensis* Sigal, qui indique des niveaux datés du Gargasien (Sigal, 1952), et que nous avons toujours trouvée en Tunisie dans le Gargasien supérieur (zone de Clansaye). Dans la coupe d'El Ariana (à 9 km. au Nord de Tunis), la microfaune à *Globigerinelloides algeriana* se situe à environ 200 mètres sous un niveau qui contient *Planulina cheniourensis* Sigal ainsi que la macrofaune suivante qui indique du Gargasien supérieur:

Douvilleiceras bigoureti Seunes
Puzosia getulina Coquand
Puzosia angladei Sayn
Phylloceras rouyanum d'Orbigny
Phylloceras guettardi Raspail
Ptychoceras laeve Matheron
Silisites seranonis d'Orbigny.

Les observations effectuées en Tunisie ont amené le second auteur (J. M.) à entreprendre l'étude détaillée du gisement type, découvert par ten Dam, mais non inventorié par lui. Les matériaux du Djebel Menaouer, qui avaient fourni *Globigerinelloides algeriana* (holotype et paratypes), nous ont livré, outre d'assez nombreux individus de cette espèce, une microfaune compagne, relativement riche, composée de nombreux Lagenidae *(Astacolus, Lenticulina, Darbyella, Pseudoglandulina, Dentalina),* de foraminifères à tests arénacés *(Haplophragmoides, Trochammina, Gaudryina, Ammodiscus),* d'Anomalinidae, de *Globorotalites* aff. *G. djaffaensis* Sigal et de globigérines (*Globigerina infracretacea* Glaessner et *G.* sp. divers). On y observe aussi quelques ostracodes. Cet ensemble

Globigerinelloides algeriana has been found at various localities near Tunis and in the Sahel (the Mediterranean coast of Algeria), associated with a microfauna consisting of Lagenidae, Anomalinidae, *Gyroidina, Globorotalites,* and *Globigerina* of the group of *G. infracretacea* Glaessner; this microfauna occurs, in all the sections studied, below a microfauna with *Planulina cheniourensis* Sigal, which indicates horizons that have been dated as Gargasian (Sigal, 1952), and which we have always found in Tunisia in the upper Gargasian (zone of Clansaye). In the El Ariana section, 9 km. north of Tunis, the microfauna with *Globigerinelloides algeriana* lies about 200 meters below a horizon that contains *Planulina cheniourensis* Sigal together with the macrofauna listed below, which indicates upper Gargasian:

Douvilleiceras bigoureti Seunes
Puzosia getulina Coquand
Puzosia angladei Sayn
Phylloceras rouyanum d'Orbigny
Phylloceras guettardi Raspail
Ptychoceras laeve Matheron
Silisites seranonis d'Orbigny.

The observations made in Tunisia led the second author (J. M.) to undertake a detailed study of the type locality, which was discovered but not exhaustively studied by ten Dam. The samples from Djebel Menaouer that furnished the holotype and paratypes of *Globigerinelloides algeriana* reveal not only numerous individuals of that species but also an accompanying microfauna, relatively rich, composed of numerous Lagenidae *(Astacolus, Lenticulina, Darbyella, Pseudoglandulina,* and *Dentalina),* arenaceous foraminifera *(Haplophragmoides, Trochammina, Gaudryina,* and *Ammodiscus),* Anomalinidae, *Globorotalites* aff. *G. djaffaensis* Sigal, and globigerines (*Globigerina infracretacea* Glaessner and *Globigerina* spp.). Some ostracodes were also observed. This assemblage is entirely

est tout à fait comparable à celui qui accompagne *Globigerinelloides algeriana* en Tunisie. Nous remarquerons de plus que le gisement algérien ne nous a fourni ni *Thalmanninella,* ni *Rotalipora,* ni *Globotruncana,* ni *Gümbelina* malgré un faciès franchement marin. Ajoutons enfin que ces formes pélagiques sont abondantes dans les formations du Crétacé moyen et supérieur des chaînes telliennes dont fait partie le Djebel Menaouer.

Nous pouvons donc conclure qu'en Algérie comme en Tunisie *Globigerinelloides algeriana* est une espèce du Crétacé inférieur. La macrofaune et la microfaune observées en Tunisie nous permettent de préciser sa position stratigraphique et de la considérer comme une bonne espèce repère pour l'Aptien d'Afrique du Nord.

similar to the one that accompanies *Globigerinelloides algeriana* in Tunisia. It should be noted, in addition, that the Algerian samples contain neither *Thalmanninella,* nor *Rotalipora,* nor *Globotruncana,* nor *Gümbelina,* although the facies is distinctly marine. Finally, we may add that these pelagic forms are abundant in the Middle and Upper Cretaceous formations of the Tellian ranges of which Djebel Menaouer is a part.

We may therefore conclude that in Algeria as well as in Tunisia *Globigerinelloides algeriana* is a Lower Cretaceous species. The macro- and microfaunas observed in Tunisia make it possible to identify its stratigraphic position, and it may be regarded as a good guide fossil for the Aptian of North Africa.

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ABSTRACT: *Coccoliths are classified into three major groups based upon the nature and arrangement of the skeletal elements as revealed by the electron microscope. It is believed that further study by this method will necessitate revisions in the taxonomy and nomenclature of the coccolithophorids. A list of recent publications on these organisms is given.*

Terminology, nomenclature, and systematics of the Coccolithophoridae

TRYGVE BRAARUD, GEORGES DEFLANDRE,
PER HALLDAL, and ERWIN KAMPTNER

The structural details of the coccoliths revealed by the electron microscope make obligatory a reconsideration of the terminology, nomenclature and systematics currently in use for the coccolithophorids. After an exchange of views, we have jointly drawn up the following propositions and declarations. This communication was first presented on July 13, 1954, at the Eighth International Congress of Botany (Paris), Section 17, Phycology. Since publication of the original paper is uncertain and will surely be much delayed, an English translation is given here. This is followed by a list of recent papers dealing with fossil and living coccolithophorids.

TERMINOLOGY

On the whole, at least temporarily, the present terminology may be retained for the coccoliths sensu lato, when studied under the ordinary microscope. Certain terms now in use, as, for example, calyptrolith, may be retained with a restricted meaning in electron microscopy.

The results already obtained in electron microscopy by the Norwegian school definitely confirm the notion of the plurality of elements in numerous coccoliths, as has already been indicated by Deflandre. They also demonstrate the existence of coccoliths of diverse forms, consisting entirely and uniquely of particles that are morphologically identical with minute crystals.

In the present state of our knowledge, the following groups can be distinguished with the electron microscope:

I. The holococcoliths, formed solely of microcrystals, which may or may not all be identical. Examples: crystalloliths from *Crystallolithus hyalinus*, calyptroliths from *Sphaerocalyptra papillifera;* zygoliths from *Homozygosphaera triarcha.*

II. The heterococcoliths, formed of an assemblage of morphologically diverse units, such as lamellae (languettes or lamelles, Lamellen), a simple or complex girdle (ceinture, Gürtel), petaloid or rim elements (éléments pétaloïdes, Randblättchen), and, in addition, more complex individual elements, among which may be mentioned:

A. cricoliths, the units arranged in a simple ring (example: *Hymenomonas carterae*).

B. cyrtoliths, in a calotte-like arrangement, with lamellae and with:

1. a center piece (renforcement médian, mittlere Verstärkung) (example: *Anthosphaera* and *Acanthoica*), or

2. a trumpet-like appendix (salpingiform cyrtolith, cyrtolithe salpingiforme, trompetenförmiger Cyrtolith) (example: *Discosphaera tubifer).*

C. caneoliths, in a basket-like arrangement with a central area, or bottom, of lamellae (aire centrale, zentrale Area), a simple or complex girdle bordered above and below by petaloid elements (example: *Syracosphaera mediterranea*).

D. placoliths, sensu structo (example: *Coccolithus huxleyi*).

E. scapholiths, in a boat-like arrangement with a central area of parallel lamellae (example: *Anoplosolenia brasiliensis* and the Calciosolenidae in general) (synonym: rhombolith sec. Halldel, 1954).

III. The pentaliths, formed of an assemblage of five trapezoidal or triangular units consisting of parallel crystallites.

NOMENCLATURE

The electron-microscope description of an old species introduces a new priority, in a strict sense, for that species. Genotype species studied in this way would imply a rediagnosis, possibly restricted, of old genera. It is desirable that changes in the definitions of genera should be based only upon observations with both the electron microscope and the ordinary microscope.

SYSTEMATICS

The systematics now in use may be tentatively retained, pending the accumulation of a sufficient number of observations with the electron microscope and the publication of facts or well-supported hypotheses concerning the relationships between genera and between families.

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ABSTRACT: *Wide distribution of Globotruncanas in the Upper Cretaceous of Tunisia shows that most of the previously described species are present and often directly linked by intermediate specimens. They have been used extensively for biostratigraphic purposes. Three new subspecies are described and synonymies are presented.*

The genus Globotruncana in Tunisia

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INTRODUCTION

The Upper Cretaceous of northern Tunisia is represented by a thick sequence of marine shales with some calcareous interbeds. The environment was favorable to life, and pelagic microfossils are widely distributed. The Globotruncanas, in particular, are represented by numerous species, most of them occurring abundantly. Their good state of preservation permits their use in detailed correlations of numerous field and well sections. The purpose of this study is to show the current use of *Globotruncana* in Tunisian biostratigraphy. In order to avoid confusion, poorly described species, the holotypes of which need to be revised, have not been used Three new subspecies of stratigraphic significance are proposed, while others are rejected as synonyms. Species are grouped into evolutionary series according to the author's ideas, when sufficiently abundant intermediate forms have been found to link them. The classification adopted here is that of Reichel (1950).

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Type specimens are deposited in the author's collection. Topotypes have been sent to the Muséum d'Histoire Naturelle in Paris and to the U. S. National Museum in Washington.

* Now with Esso-Standard, Bègles, France.

SUBGENUS TICINELLA REICHEL, 1950

This subgenus appears in the Albian lower Fahdene formation, where it is rather frequently represented by *Ticinella roberti* (Gandolfi, 1942). It is generally impossible to detect the accessory apertures unless specialized techniques are used in treating the specimens. It was noted by Reichel (1950) that similar forms of the Anomalinidae are associated with *T. roberti* in the Breggia area. The same situation is observed in Tunisia, where many specimens cannot be attributed either to one group or to the other until the presence or absence of multiple apertures has been determined. Identified *Ticinella* specimens, however, correspond exactly with the description and figures given by Reichel (1950).

SUBGENUS THALMANNINELLA SIGAL, 1948

This subgenus is first represented by *Thalmanninella ticinensis* (Gandolfi, 1942) and its variety *alpha*. The latter appears slightly below the typical form in several sections. Observations made by the writer confirm completely the evolution of *Thl. ticinensis* into *Rotalipora appenninica* (O. Renz, 1936). Numerous specimens with intermediate characteristics, such as a reduced number of chambers in the last whorl and a more rapidly increasing spiral, are observed prior to the appearance of typical specimens of *Rtl. appenninica*. The specific classification of such forms is impossible, and they must be grouped with one or the other species according to the stage of their evolution. On the other hand, no specimens intermediate between *Thl. ticinensis* and *Ticinella roberti* have been noted so far.

Thalmanninella brotzeni Sigal, 1948, is abundant in younger sediments. It appears shortly after *Rtl. appenninica typica* (Gandolfi, 1942). These forms closely resemble one another. When secondary apertures are not visible, which usually happens, it is generally possible to distinguish *Thl. brotzeni* from *Rtl. appenninica typica* by the smaller size and especially by the continuity of the periumbilical "keel" of the former. The chambers of the last whorl are close to one another on the ventral side in *Thl. brotzeni*, while they are separated by the secondary apertures in *Rtl. appenninica typica*. No intermediate forms were observed between *Thl. ticinensis* and *Thl. brotzeni*.

SUBGENUS ROTALIPORA BROTZEN, 1942

Group appenninica: As mentioned above, the appearance of this subgenus is preceded by specimens transitional between *Thalmanninella ticinensis* and *Rotalipora appenninica appenninica* (O. Renz, 1936). The latter evolved throughout the Cenomanian, and all the stages of this evolution are easily observed in Tunisia. Several subspecies were described by Gandolfi and others, and many new ones could be selected among the various forms encountered. The writer sees no use in encumbering the nomenclature, and prefers to recognize a wider concept for the species. The following stages can be selected for stratigraphic purposes in this evolutionary series:

(a) The forms that developed out of *Thalmanninella ticinensis* are simple and not ornamented except for the keel. Their outstanding characteristic is the rapid increase in size in the last few chambers. They correspond to *Rotalipora appenninica appenninica*.

(b) The first sign of ornamentation appears as an elevation and thickening of the inner (periumbilical) part of the chambers between the secondary apertures on the umbilical side. Such forms are classified as *Rotalipora appenninica alpha* (Gandolfi, 1942) (Reichel, 1950, p. 605, fig. 3) (text-figs. 1-2).

(c) This ornamentation develops into raised sutures on the ventral side, which becomes more convex as the spiral side acquires more strongly limbate sutures. Forms of this group belong to *Rotalipora appenninica typica* (Gandolfi, 1942) (although the term *"typicus"* is to be avoided as a specific or subspecific name, *Rtl. appenninica typica* (Gandolfi, 1942) is considered valid as it was correctly figured by Gandolfi (1942) in text-fig. 42, no. 2-3, pl. 2, fig. 6a-c, and pl. 4, fig. 13, and described on pp. 116-123, 149, and 151). *Rotalipora globotruncanoides* Sigal, 1948, is considered a synonym (Mornod, 1950, p. 583) (text-fig. 3).

(d) The final stage of the evolutionary series was described (Mornod, 1950) as a separate species, *Rotalipora reicheli* Mornod, 1950. This author gave specific rank to this form because of its very distinctive characters: It is convex with very little ornamentation on the umbilical side, flat with a small central cone and strongly thickened sutures on the spiral side. Specimens intermediate between stages (c) and (d) are not very frequent, but are undoubtedly present.

These evolutionary stages correspond to various strata, and are very useful for correlation in the Cenomanian.

Group cushmani-turonica: Rotalipora cushmani (Morrow, 1934) is commonly represented by typical specimens in the upper Cenomanian. It appears suddenly, without known ancestors. Some specimens with a tendency toward uncoiling, as shown by the strongly protruding last chamber, correspond to the description of *Rotalipora cushmani* var. *evoluta* Sigal, 1948. This variety was given specific rank by Reichel (1950, footnote 9), but Tunisian specimens are too close to the type species to deserve any rank other than variety.

Rotalipora turonica Brotzen, 1942, which shows many features similar to those of *Rtl. cushmani*, was not found in its typical form. Our specimens always lack the pustulate ornamentation of the type and are referred to as *Rotalipora* cf. *R. turonica*.

SUBGENUS GLOBOTRUNCANA SENSU STRICTO, CUSHMAN, 1927

Group stephani-imbricata: The first occurrence of *Globotruncana* s.s. seems to be *Globotruncana stephani* Gandolfi, 1942, which appears during the Cenomanian. This small species is irregularly present in the samples and never common. It evolves into a characteristic conical form, *Glt. stephani turbinata* Reichel, 1950, in the upper Cenomanian. This subspecies is commonly found associated with *Rotalipora cushmani* and *Thalmanninella brotzeni*. It is replaced later by *Globotruncana imbricata* Mornod, 1950, which is approximately the same size, but possesses two keels imbricated in a very characteristic way. Our observations agree completely with those reported by Mornod (1950) from Switzerland.

Group helvetica-ventricosa: The upper Cenomanian — lower Turonian is marked by the decrease and disappearance of *Rotalipora* and *Thalmanninella*, the sudden expansion of *Gümbelina*, and an abundance of large *Globigerina*. The origin of *Globotruncana* from *Globigerina* has been proposed and discussed several times, and as often discarded. However, it is interesting to note, first, that the primitive forms of *Globotruncana* sensu lato are more or less globigeriniform

(Ticinella roberti, Thalmanninella ticinensis, Globotruncana stephani), and secondly, that they originated in environments rich in *Globigerina.* These conditions apply fairly well to *Globotruncana helvetica* Bolli, 1945, in which the keel appears by gradual stages. The primitive specimens show, near the periphery on each chamber of the last whorl, a slight protuberance that develops gradually into a partial keel, and then into a complete keel. *Globotruncana helvetica* is a very distinctive species that is common and restricted to strata of upper Turonian age. The earliest specimens are associated with *Rotalipora reicheli.* Very rare double-keeled Globotruncanas of the *lapparenti angusticarinata* type are found together with the more highly evolved form of *Globotruncana helvetica.*

Globotruncana ventricosa White, 1928 (syn.: *Globotruncana canaliculata* (Reuss) var. *ventricosa* White, 1928), is one of the species for which the holotype should be accurately described. The writer has provisionally adopted the concept of this species held by European authors such as Cita (1948) and Mornod (1950), pending the revision of the holotype. The number and disposition of the chambers, their globigeriniform aspect on the ventral side, the two keels close to one another, and the radial umbilical sutures support this opinion. The vertical range of this species extends farther downward in Europe and North Africa than on the American continent. White records it mostly from the upper Papagallos, just below *Glt. calcarata* and together with it. Bolli (1951) reports *Glt. ventricosa* from Trinidad as restricted to the Maestrichtian, although most probably the *"Glt. ventricosa"* specimens from the Maestrichtian belong to *Glt. gagnebini* Tilev, 1952 (for example, Bolli, 1951, p. 190, fig. 1e). Although it is possible that its range in America differs somewhat from that in Europe and North Africa, it is also possible that two different species are referred to by the same name.

Globotruncana ventricosa of European authors is a very useful species, the evolution of which is very clearly seen in the lower Senonian. It appears first in Tunisia as specimens with very moderately inflated chambers on the umbilical side. The spiral side is flat or very slightly concave and does not evolve as does the umbilical side. At first the two keels are very close, almost fused. This species evolves by the development of the chambers on the umbilical side. They become strongly inflated and globigeriniform, as in *Globotruncana helvetica,* while the two keels separate and become very distinct. Finally, the ventral side of the chambers becomes somewhat conical, and the beginning of a third keel appears at the top of each chamber and develops into a well-marked periumbilical keel. This evolutionary series is of biostratigraphic importance beyond Tunisia, as several different forms have already been described from other countries. The writer therefore proposes the following nomenclature:

Globotruncana ventricosa primitiva Dalbiez, n. subsp., for the low-chambered specimens (syn.: *Glt. ventricosa* White, of Cita, 1948, pl. 4, fig. 9).

Glt. ventricosa ventricosa White, 1928, for the high-chambered specimens (syn.: *Rotalia concavata* Brotzen, 1934; *Glt. ventricosa* White, of Mornod, 1950 (part), text-fig. 12(1a-c); *Glt. asymetrica* Sigal, 1952).

Glt. ventricosa carinata Dalbiez, n. subsp., for the "tricarinate" specimens (syn.: *Glt. ventricosa* White, of Mornod, 1950 (part), text-fig. 12(2a-c); *Glt. ventricosa* White, of Carbonnier, 1952, pl. 6, fig. 1a-c; *Glt.* aff. *concavata* (Brotzen), of de Klasz, 1953, pl. 6, fig. 2a-c).

If *Glt. ventricosa* as defined here is shown to be different from *Glt. ventricosa* White, 1928, after revision of the type, the three subspecies proposed above will have to be called *Glt. concavata* (Brotzen) subsp. *primitiva* Dalbiez. *Glt. concavata concavata* (Brotzen), and *Glt. concavata* (Brotzen) subsp. *carinata* Dalbiez, according to the Rules of Nomenclature. The evolutionary relationship between *Glt. helvetica* and *Glt. ventricosa* is doubtful.

Group schneegansi-sigali-cretacea: Glt. schneegansi Sigal, 1952, was figured but not described from Algeria. *Globotruncana sigali* Reichel, 1950, previously reported as *Rotalipora appenninica* (Renz) (Sigal, 1949), also occurs there. Both species occur in Tunisia, but typical specimens are scarce and intermediate forms are common.

Globotruncana cretacea Cushman, 1938, is a poorly described but much discussed species. Reichel (1950, pp. 608-615) classified *Glt. cretacea* with the single-keeled forms, whereas Bolli (1951, p. 192) classified it with the double-keeled forms. This species cannot be used effectively until the holotype and topotypes are revised and compared with the forms mentioned above.

Group elevata-rosetta-stuarti: This group needs a complete revision, since wide discrepancies as to its vertical range, and confusion as to the diagnoses of forms, are both evident in the literature. This task is beyond the scope of this paper, but some nomenclatural modifications are proposed in order to increase its biostratigraphic usefulness. *Globotruncana stuarti,* for example, is recorded as appearing in the uppermost Coniacian—basal Santonian in Algeria (Sigal, 1952, range chart);

in the Campanian of Italy (Cita, 1948), France, and Trinidad (Bolli, 1951); and at or near the Campanian—Maestrichian boundary in Israel (Reiss, 1952) and Morocco. It is the writer's opinion that such discrepancies, especially in Europe and North Africa, are a result more of different interpretations of the species than of differences in its vertical range. Numerous stratigraphic sections have shown *Globotruncana stuarti* to be definitely restricted to the upper Campanian and Maestrichtian in Tunisia, while other species of this group appear much earlier.

It is probable that the group originated from *Globotruncana sigali*, but this has not yet been demonstrated. *Globotruncana elevata* (Brotzen, 1934) appears first and is typically characterized by numerous chambers with rounded margins, which give it a distinctly lobate contour; a single keel; a slightly conical center of the spiral side and a strongly convex ventral side. This form is here called *Globotruncana elevata elevata* (syn.: *Rotalia elevata* Brotzen, 1934, and *Glt. andori* de Klasz, 1953) and shows a variable overlapping of the chambers on the spiral side.

Globotruncana elevata stuartiformis Dalbiez, n. subsp., differs from *Glt. elevata elevata* in the broken, angular margin of the last-formed chambers, and in the slightly to distinctly lower umbilical side. The first specimens of *Glt. elevata stuartiformis* sometimes occur with the first specimens of *Glt. elevata elevata*, a fact which may explain the reports of *Glt. stuarti* from the lower Campanian. *Glt. elevata elevata* does not change markedly, while *Glt. elevata stuartiformis* becomes more and more angular at the peripheral margin of the last-formed chambers, until they have a nearly triangular form on the spiral side. Finally, *Glt. elevata stuartiformis* develops into the characteristic *Glt. stuarti* during the upper Campanian, when the last-formed chambers on the spiral side become trapezoidal.

The evolution and the distinctive characters of these three types may be summarized as follows:

Glt. elevata elevata (Brotzen): All chambers petaliform and depressed on the spiral side. Periphery lobate. Central cone raised. Umbilical side very strongly convex throughout.

Glt. elevata stuartiformis Dalbiez, n. subsp.: Periphery of the last-formed chambers angular, last-formed chambers becoming nearly triangular on the spiral side. Periphery moderately lobate to smooth; central cone slightly raised. Umbilical side moderately convex, becoming strongly convex in the last chambers.

Glt. stuarti (de Lapparent, 1918): Last-formed chambers trapezoidal on the spiral side, periphery smooth. No central cone. Umbilical side moderately to strongly convex (text-fig. 4).

Globotruncana sp. 1 of de Klasz (1953, pl. 7, fig. 1) appears to be a *Globotruncana elevata elevata* with a tendency toward *Glt. elevata stuartiformis*, as shown by the reduced convexity of the ventral side and the moderately lobate periphery. *Glt. andori* de Klasz, 1953, is considered to be a synonym of *Glt. elevata elevata*, as the slight overlap of the chambers on the spiral side is not believed to be sufficient to make it a new species or even a new subspecies. Many forms identified as *Globotruncana rosetta* (Carsey, 1926) correspond to *Glt. elevata elevata*. In fact, Carsey's description is somewhat confusing and her figures are not sufficiently good (there is no side view) to show clearly that *Glt. rosetta* and *Glt. elevata elevata* are different. A study of topotype material is necessary in order to solve this problem, although, judging from Carsey's figures, the chambers of *Glt. rosetta* are less numerous and increase more rapidly on the spiral side than those of *Globotruncana elevata elevata*.

Group lapparenti-arca: As mentioned before, the first specimens of this group to appear are rare forms of the *Globotruncana lapparenti angusticarinata* group, found in the *Glt. helvetica*-bearing beds. The various subspecies of the group *lapparenti* are widely represented later, particularly the very characteristic subspecies *coronata* Bolli, 1944, *angusticarinata* Gandolfi, 1942, *lapparenti* Brotzen, 1936, and *tricarinata* (Quereau, 1893), given in the order of their stratigraphic occurrence. The other subspecies are not well represented in Tunisia.

It seems reasonable to conclude that *Globotruncana arca* (Cushman, 1926), as figured originally and again by Cushman in 1946 (pl. 62, fig. 4a-c, not fig. 5a-c), developed directly from *Glt. lapparenti tricarinata*. This evolution was more or less suggested by Vogler (1941) and Cita (1948), and is substantiated morphologically and stratigraphically in Tunisia. As shown in our text-figure 5, the Tunisian forms are close to *Glt. arca* (Cushman), but all transitional stages between *Glt. lapparenti tricarinata* and *Glt. arca* occur commonly before the first appearance of typical specimens of *Glt. arca*.

Group fornicata-calciformis-contusa: The first specimens of *Glt. fornicata* Plummer, 1931, that occur in Tunisia are similar to the type, but the number of chambers in the last whorl varies considerably, later on. Cita (1948) discussed this group rather fully.

The writer agrees that *Globotruncana fornicata, Glt. calciformis* Vogler, 1941 (syn.: *Globotruncana linnei* (d'Orbigny) subsp. *calciformis* Vogler, 1941; *Rosalina linnei* d'Orbigny "mut. calciforme" de Lapparent, 1918), and *Glt. contusa* (Cushman, 1926) are three stages in the evolution of a single branch of the *Globotruncana* line, since forms intermediate between the typical specimens are very frequent.

Group conica-falsostuarti: Globotruncana conica White, 1928, is represented in the Campanian by small to medium-sized specimens. They are typically planoconvex to concavoconvex, as is the case in White's form. They evolve into a biconvex species of larger size, with the chambers parting near the umbilicus on the ventral side. This is *Glt. falsostuarti* Sigal, 1952, which may be considered as a subspecies of *Glt. conica*. Bolli's figured specimens of *Glt. conica* (1951, pl. 34, figs. 13-15) appear to belong to *Glt. falsostuarti*. This is confirmed by the vertical range ascribed to this species by Bolli. The writer sees no reason to maintain that such different species as *Glt. arca* and *conica* are related, as suggested by Cita (1948, p. 150). The relationships between *Glt. stuarti* and *conica* are also very doubtful.

Other species: Globotruncana benacensis Cita, 1948, has not been found in Tunisia, although some lower Turonian forms are closely allied to it. They are much more lobate, however, and have practically no distinct keel.

Only one specimen of *Globotruncana renzi* Gandolfi, 1942, has been found in Tunisia. This species seems questionable, as Gandolfi figured one specimen (1948, pl. 3, fig. 1a-c) of *Glt. renzi* that differs from *Glt. lapparenti angusticarinata* only in the reduced number of chambers in the last whorl (there are five instead of seven). This is not a suitable character on which to base a new species or subspecies. Moreover, few references to the typical form have been published since, although detailed studies of equivalent horizons have been made. In the writer's opinion, *Globotruncana renzi* Gandolfi, 1942, is synonymous with *Glt. lapparenti angusticarinata* Gandolfi, 1942. *Glt. renzi* Thalmann, 1942, of which Gandolfi's name is a junior homonym, can be considered a different species.

Globotruncana calcarata Cushman, 1927, is represented in a very restricted horizon at the Campanian – Maestrichtian boundary by numerous specimens identical with Cushman's type. They evolve rapidly into a more convex form, which was figured from Algeria by Sigal (1952, fig. 43).

Globotruncana citae Bolli, 1951, is rather frequent in the Maestrichtian, while *Glt. gansseri* Bolli, 1951 (syn.: *Glt. lugeoni* Tilev, 1952), is frequent to common in the middle part of this stage. Specimens showing some affinity to *Glt. gansseri*, such as *Globotruncana* sp. 2 of de Klasz (1953, pl. 7, fig. 2a-c), and double-keeled forms of this group, such as *Glt. gagnebini* Tilev, 1952, are also numerous in the upper Maestrichtian.

Glt. mayaroensis Bolli, 1951, was kindly shown to the writer by Mr. Glintzboeckel, micropaleontologist with SEREPT. A few specimens were found later on by the writer in some Maestrichtian samples from northern Tunisia.

Many other forms are present in the Senonian, but are not described here in order to avoid confusion. Much literature on the subject is now in press or has been issued very recently and is not yet available. Much more work needs to be done on the Tunisian Globotruncanas before they will be accurately known.

BIOSTRATIGRAPHY

The Globotruncanas discussed above are very useful for correlation and for biostratigraphic studies. They are used commonly in Tunisia for detailed correlations of field and well sections. The stratigraphic ranges of the most important species are shown in the accompanying charts. The thickness of the formations is not drawn to scale, as it is too variable. The lithology has been shown schematically, the lithologic units varying slightly with respect to the faunizones. A faunizonal scale is also shown in the charts, but other zones could just as well have been selected and much more detailed divisions given if desired. Finally, the bottom line of each chart shows the approximate correspondence between faunizones and geologic age.

It is noteworthy that, according to most authors, the order of appearance of the species of *Globotruncana* does not vary greatly in the Mediterranean area and elsewhere. Exception must, of course, be made for forms such as *Glt. arca* and *Glt. rosetta*, and for misidentified specimens. However, the vertical ranges of the species are interpreted in various ways, and the geologic age attributed to a given species varies more or less according to authors, within a single area or even in a single section. The example of *Glt. stuarti* has been noted above, but many others are to be found in the literature. This may be a result of:

(a) Variations in the concept of the species, which is one of the most difficult problems for the paleontologist dealing with an evolutionary plexus. Only a few specimens correspond to the type description of a given species, whereas most specimens show more or less important morphologic variations. This difficulty can be partly avoided, however, either by describing

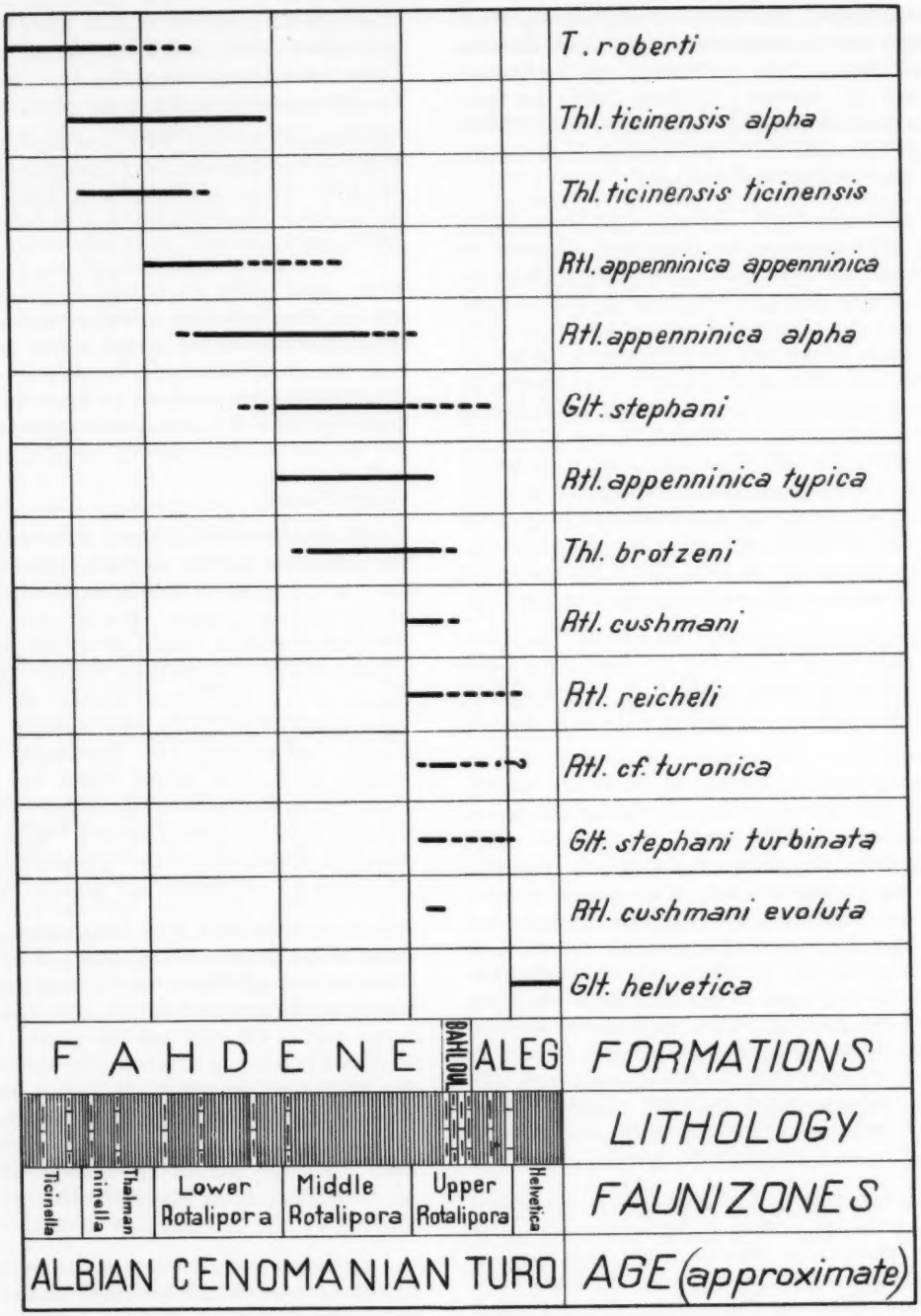
T. roberti
Thl. ticinensis alpha
Thl. ticinensis ticinensis
Rtl. appenninica appenninica
Rtl. appenninica alpha
Glt. stephani
Rtl. appenninica typica
Thl. brotzeni
Rtl. cushmani
Rtl. reicheli
Rtl. cf. turonica
Glt. stephani turbinata
Rtl. cushmani evoluta
Glt. helvetica
FAHDENE
BAHLOUL
ALEG
FORMATIONS
LITHOLOGY
Ticinella
Thalmaninella
Lower Rotalipora
Middle Rotalipora
Upper Rotalipora
Helvetica
FAUNIZONES
ALBIAN
CENOMANIAN
TURO
AGE (approximate)

CHART 1

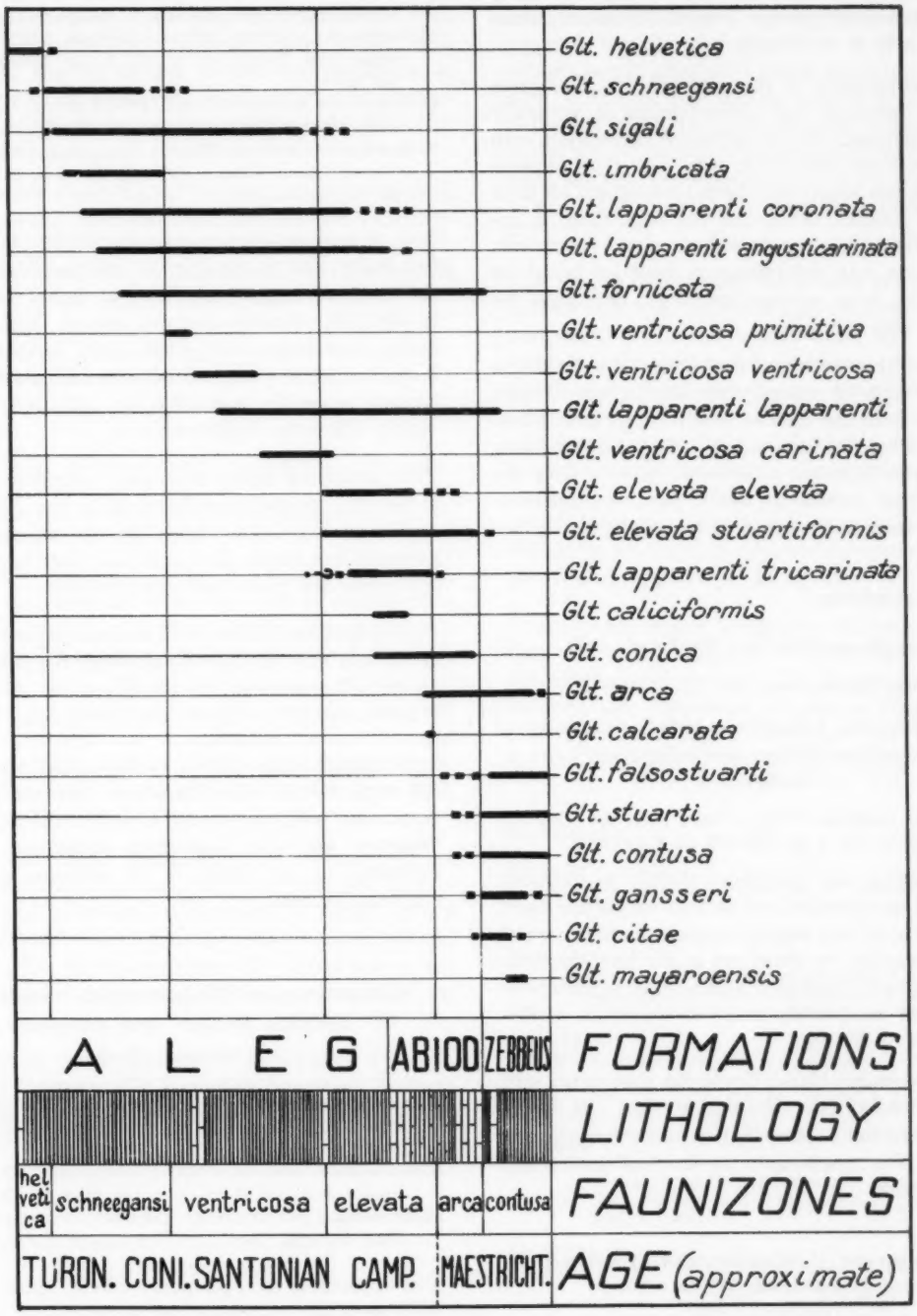
Glt. helvetica
Glt. schneegansi
Glt. sigali
Glt. imbricata
Glt. lapparenti coronata
Glt. lapparenti angusticarinata
Glt. fornicata
Glt. ventricosa primitiva
Glt. ventricosa ventricosa
Glt. lapparenti lapparenti
Glt. ventricosa carinata
Glt. elevata elevata
Glt. elevata stuartiformis
Glt. lapparenti tricarinata
Glt. caliciformis
Glt. conica
Glt. arca
Glt. calcarata
Glt. falsostuarti
Glt. stuarti
Glt. contusa
Glt. gansseri
Glt. citae
Glt. mayaroensis
A L E G
ABIOD
ZEBBEUS
FORMATIONS
LITHOLOGY
helveti ca
schneegansi
ventricosa
elevata
arca
contusa
FAUNIZONES
TURON.
CONI.
SANTONIAN
CAMP.
MAESTRICHT.
AGE (approximate)

CHART 2

the plexus or by giving a statement of the variability of newly described species. Trinominal nomenclature is of great help in such cases.

(b) Misidentification of the geologic age. This error is very frequent, as age determination is generally an approximation, without sufficient correlation with the type sections. Moreover, very few type sections of the European stages have been investigated for their microfossil content. When this has been done, it appears that they are often devoid of pelagic specimens. In such cases, age determination must be based on criteria other than micropaleontology, and must be considered very carefully.

These difficulties emphasize the advantages of using a faunizonal scale of pelagic microfossils, which scale varies little from one area to another. Age determinations, which are indispensable, remain approximate and are under constant adjustment as new data are obtained from techniques other than micropaleontology and from new studies of type sections.

SYSTEMATIC DESCRIPTIONS

Genus GLOBOTRUNCANA Cushman, 1927

Subgenus GLOBOTRUNCANA Cushman, 1927

Globotruncana (Globotruncana) ventricosa primitiva Dalbiez, new subspecies
Text-figure 6

Globotruncana ventricosa White. – CITA, 1948, Riv. Ital. Pal. Strat., vol. 54, no. 4, pp. 162-163, pl. 4, fig. 9a-c.

Test of medium size, periphery slightly to distinctly lobate with one double keel or two very close keels. Spiral side flat to very slightly concave; sutures curved, limbate; generally six chambers in the last whorl, increasing regularly. Umbilical side with wide umbilicus; generally six moderately inflated chambers visible. Diameter ca. 0.495 mm.

Approximate range: Upper Coniacian. Associated with *Glt. sigali* Reichel, *Glt. schneegansi* Sigal, *Glt. lapparenti angusticarinata* Gandolfi, *Glt. lapparenti coronata* Bolli. Rare. The type is from Le Kef-Mellegue, northwestern Tunisia.

Globotruncana (Globotruncana) ventricosa ventricosa White
Text-figure 7a-d

Globotruncana canaliculata (Reuss) var. *ventricosa* WHITE, 1928, Jour. Pal., vol. 2, no. 4, p. 284, pl. 38, fig. 5a-c.

Rotalia concavata BROTZEN, 1934, Deutsch. Ver. Palästinas, Zeitschr., vol. 57, p. 66, pl. 3, fig. b.

Globotruncana ventricosa White. – CUSHMAN, 1946, U. S. Geol. Survey, Prof. Papers, no. 206, p. 150, pl. 62, fig. 3a-c.

Globotruncana ventricosa White. – MORNOD, 1950 (part), Eclogae Geol. Helv., vol. 42, no. 2, pp. 590-591, text-fig. 12(1a-c).

Globotruncana asymetrica SIGAL, 1952, Internat. Geol. Congr., 19th, Monogr. Rég., ser. 1, no. 26, text-fig. 35.

Globotruncana ventricosa White. – NAKKADY and OSMAN, 1954, Internat. Geol. Congr., 19th, C. R., fasc. 15 (sec. 13), pl. 19, fig. 9A(a-c).

Test of medium size, periphery distinctly lobate with two keels close to one another and parallel except on the apertural face, where they part. Spiral side slightly to distinctly concave; sutures curved, limbate; generally six chambers in the last whorl, increasing regularly. Umbilical side with wide umbilicus, filled with foreign material; generally six globular chambers visible. Diameter 0.495 mm.

This subspecies differs from *Glt. ventricosa primitiva* in the strongly globular chambers on the ventral side, and in the two distinct keels close to one another but generally not fused. *Glt. gagnebini* Tilev has a convex spiral side and pustulose ornamentation.

Rotalia deeckei Franke, 1925, belongs to the *ventricosa* group and may be synonymous with the present subspecies. Comparisons of topotypes of White's and Franke's species would be necessary to solve this point.

Approximate range: Lower Santonian. Associated with *Glt. sigali* Reichel, *Glt. lapparenti coronata* Bolli, *Glt. lapparenti angusticarinata* Gandolfi, *Glt. fornicata* Plummer and *Glt. lapparenti lapparenti* Brotzen. Frequent to abundant in all sections studied in northern Tunisia.

Globotruncana (Globotruncana) ventricosa carinata Dalbiez, new subspecies
Text-figure 8a-d

Globotruncana ventricosa White. – MORNOD, 1950 (part), Eclogae Geol. Helv., vol. 42, no. 2, pp. 590-591, text-fig. 12(2a-c).

Globotruncana ventricosa White. – CARBONNIER, 1952, Soc. Géol. France, Bull., sér. 6, vol. 2, p. 116, pl. 6, fig. 1a-c.

Globotruncana aff. *concavata* (Brotzen). – DE KLASZ, 1953, Geol. Bavarica, no. 17, pp. 236-237, pl. 6, fig. 2a-c.

Test of medium size, periphery lobate. Spiral side and keels as in *Glt. ventricosa ventricosa* White. Umbilical side with wide umbilicus; six chambers generally visible, slightly globular and pustulate, subconical or roof-shaped, each developing a distinct partial "keel" at its top. Diameter 0.850 mm.

This subspecies differs from *Glt. ventricosa ventricosa* in the less globular, somewhat conical chambers on the umbilical side, each bearing a more or less well developed keel at its top, around the umbilicus. It differs from *Glt. gagnebini* Tilev in the same characteristics and in the concavity of the spiral side in *Glt. ventricosa carinata*.

Approximate range: Upper Santonian. Associated with *Glt. lapparenti coronata* Bolli, *Glt. lapparenti angusticarinata* Gandolfi, *Glt. fornicata* Plummer, and *Glt. lapparenti lapparenti* Brotzen. Frequent. The type is from Le Kef-Mellegue, northwestern Tunisia.

Globotruncana (Globotruncana) elevata elevata (Brotzen)

Text-figure 9a-c

Rotalia elevata Brotzen, 1934, Deutsch. Ver. Palästinas, Zeitschr., vol. 57, p. 66, pl. 3, fig. c.

Globotruncana andori de Klasz, 1953, Geol. Bavarica, no. 17, pp. 233-235, pl. 6, fig. 1a-c.

Test large, periphery distinctly lobate, acute transversally, single-keeled. Spiral side flat or slightly convex with a raised central cone; chambers numerous, petaliform; five to nine moderately depressed chambers in the last whorl, slightly overlapping in some specimens; sutures curved, not angular, limbate. Umbilical side very strongly convex, chambers flush or slightly inflated; sutures flush to slightly depressed, limbate; periumbilical part of the chambers with a faint keel; umbilicus large, deep. Diameter ca. 0.800 mm.

This species differs from *Glt. rosetta* (Carsey) in its more numerous chambers, which increase less rapidly in size, and in its spiral side, which is flatter, with a distinct central cone. *Glt. elevata stuartiformis* Dalbiez, n. subsp., has angular sutures on the spiral side, a less marked central cone, and a distinctly lower umbilical side.

Approximate range: Campanian. Associated with *Glt. fornicata* Plummer, *Glt. lapparenti lapparenti* Brotzen, and *Glt. elevata stuartiformis* Dalbiez, n. subsp. Frequent.

Globotruncana (Globotruncana) elevata stuartiformis Dalbiez, new subspecies

Text-figure 10a-c

Globotruncana (Globotruncana) stuarti (de Lapparent). – Papp and Küpper, 1953, Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 162, no. 1-2, pl. 2, fig. 2a-c.

Test medium to large, periphery moderately to slightly lobate, acute transversally, single-keeled. Spiral side slightly convex, centrally more or less vaulted; chambers numerous, flat to slightly depressed, nearly triangular; five to nine chambers in the last whorl; sutures nearly tangential to the preceding whorl, limbate. Umbilical side slightly convex at the beginning of the last whorl, becoming strongly convex at the end of this whorl; chambers flat to slightly inflated; sutures even, limbate; periumbilical part of the chambers with a small keel. Umbilicus large and deep. Diameter 0.850 mm.

This species differs from *Glt. elevata elevata* (Brotzen) in the less convex umbilical side, the moderately lobate periphery, the lower central cone, and the angular contour of the last-formed chambers on the spiral side, which gives these chambers a somewhat triangular, instead of a petaliform, shape. *Glt. stuarti* (de Lapparent) has a more convex umbilical side, an even periphery, no central cone, and its chambers are trapezoidal on the spiral side. Many specimens identified as *Glt. stuarti* from the upper Santonian and Campanian undoubtedly belong to the present subspecies (for example, Cushman, 1946, pl. 62, fig. 5a-c).

Approximate range: Campanian to lower Maestrichtian. Associated with *Glt. elevata elevata* (Brotzen), *Glt. fornicata* Plummer, *Glt. lapparenti lapparenti* Brotzen, *Glt. lapparenti tricarinata* (Quereau), and *Glt. calciformis* Vogler. Common. The type is from Le Kef-Mellegue, northwestern Tunisia.

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EXPLANATION OF TEXT-FIGURES 1-10

TEXT-FIGURES 1-3

1, *Globotruncana (Rotalipora) appenninica alpha* Gandolfi, 1942; umbilical side. 2, *Globotruncana (Rotalipora) appenninica alpha* Gandolfi, 1942; umbilical side of a specimen transitional to *Globotruncana (Rotalipora) appenninica typica* Gandolfi. 3, *Globotruncana (Rotalipora) appenninica typica* Gandolfi, 1942; umbilical side of a primitive specimen. All figures × 45.

TEXT-FIGURE 4

Globotruncana (Globotruncana) stuarti (de Lapparent) 1918. a, spiral side; b, umbilical side; c, side view. All figures × 45.

TEXT-FIGURE 5

Globotruncana (Globotruncana) arca (Cushman) 1926. a, spiral side; b, umbilical side; c, peripheral view of another specimen. All figures × 45.

TEXT-FIGURE 6

Globotruncana (Globotruncana) ventricosa primitiva Dalbiez, n. subsp. Side view of holotype, × 45.

TEXT-FIGURE 7

Globotruncana (Globotruncana) ventricosa ventricosa White. a-c, plesiotype: a, spiral side; b, umbilical side; c, side view; d, another specimen, peripheral view. All figures × 45.

TEXT-FIGURE 8

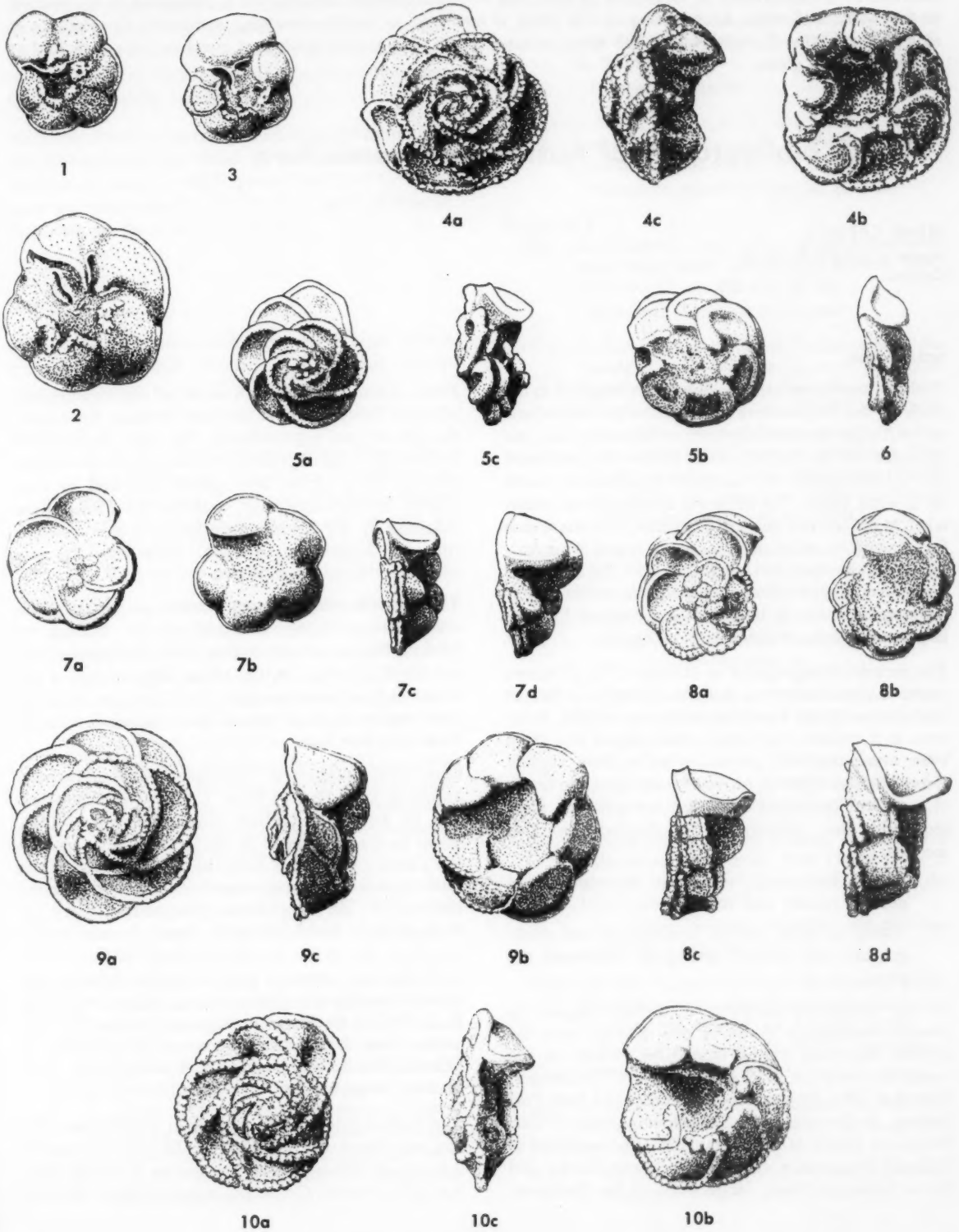
Globotruncana (Globotruncana) ventricosa carinata Dalbiez, n. subsp. a-c, holotype: a, spiral side; b, umbilical side; c, side view; d, another specimen, peripheral view. All figures × 45.

TEXT-FIGURE 9

Globotruncana (Globotruncana) elevata elevata (Brotzen) 1934. Plesiotype. a, spiral side; b, umbilical side; c, side view. All figures × 45.

TEXT-FIGURE 10

Globotruncana (Globotruncana) elevata stuartiformis Dalbiez, n. subsp. Holotype. a, spiral side; b, umbilical side; c, side view. All figures × 45.


1
3
4a
4c
4b
2
5a
5c
5b
6
7a
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7d
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8b
9a
9c
9b
8c
8d
10a
10c
10b

ABSTRACT: *A bibliography of references to fossil and Recent Australian foraminifera is presented. It is arranged in two sections. Section A, consisting of 105 titles, is restricted to works containing systematic descriptions of new forms. Section B, consisting of 248 titles, contains works of a general geological character in which lists of foraminifera are given.*

A bibliography of Australian foraminifera

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Canberra

INTRODUCTION

With the increasing number of workers engaged in the study of the foraminifera in Australia and elsewhere, and with the increased amount of literature that has appeared on the subject since 1930, it is considered that a bibliography of Australian foraminifera would be of some value. The intensive investigations undertaken in the last few years in connexion with the search for oil, with its ultimate discovery in North-West Australia in December, 1953, together with the important part played by the micropalaeontologists in this exploratory work, make it necessary for workers to have literature on foraminifera easily accessible.

The present bibliography is an attempt to list all known works in which reference is made to fossil and Recent foraminifera in the Australian region up to 1954. However, it is realised that some small papers may have been overlooked. All papers, whether they contain systematic descriptions, or refer to stratigraphy, or are of a general geological character, are included. Consequently, this bibliography is divided into two sections:

(A) Works containing systematic descriptions of genera, species and varieties;

(B) Works in which lists of foraminifera and stratigraphic and general geological references are given.

It was considered desirable to include papers on Recent foraminifera in which new species were described from seas in the immediate vicinity of the Australian coastline, such as those in the "Challenger" Report of 1884. New species were described from Port Jackson, in the vicinity of Sydney, New South Wales; Moncoeur Island in Bass Strait, 10 miles southeast of Wilson's Promontory, Victoria; and from Booby and Raine Islands in Torres Strait, north of the Continent. Heron-Allen and Earland's work on the foraminifera of Lord Howe Island is included because this island, though situated approximately 500 miles northeast of Sydney, is included politically in the electorate of East Sydney. Many of the new species described by Parr (1950) in his magnificent work on the foraminifera collected by the British Australian and New Zealand Antarctic Expedition, 1929-1931, came from the seas around southeastern Australia.

The numerous departmental records prepared by the micropalaeontologists attached to the Bureau of Mineral Resources and relating to the foraminifera are not listed, although certain Mines Departments of the States of the Commonwealth that have been supplied with copies of these records have included them in their reference lists.

Short bibliographies of Australian foraminifera have appeared from time to time. The most complete one was on Australian Tertiary foraminifera up to 1941, given by the late Dr. F. A. Singleton in his paper on the Tertiary geology of Australia (1941). Many of the rarer papers listed were found amongst the charred remains of the magnificent Chapman Library on Foraminifera, which suffered severe damage in the disastrous fire at the Bureau in April, 1953, or in the card catalogue prepared prior to the fire. Acknowledgment of assistance is given to many helpers, especially E. D. Gill of the National Museum, Melbourne. The author also thanks the Director of the Bureau of Mineral Resources, Geology and Geophysics, Melbourne, for permission to publish this bibliography.

The earliest reference to Australian foraminifera that has been found was in 1843, when Ehrenberg recorded a species of *Biloculina* and two species of *Rotalia* from Australian waters. Carpenter, in his works of 1850 and

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1856, made reference to and figured some larger forms of Recent foraminifera. The earliest reference to fossil foraminifera appears to be that by Parker and Jones in 1860, in which they described a bryozoan limestone from Mt. Gambier, South Australia.

All forms described in the publications in Section A of the bibliography are listed for the convenience of workers. In cases in which species described by Cushman are redescribed in his Monographs and Special Publications, these are also listed.

SECTION A

Publications containing systematic descriptions of new genera, species and varieties of Australian foraminifera, with lists of new forms therein:

BRADY, H. B.

1879 – *Notes on some of the reticularian Rhizopoda of the "Challenger" Expedition; II – Additions to the knowledge of the porcellanous and hyaline types.* Quart. Jour. Micr. Sci., new ser., vol. 19, pp. 261-299, pl. 8.

Frondicularia compta.

1881 – *Notes on some of the reticularian Rhizopoda of the "Challenger" Expedition; III – 1) Classification; 2) Notes on new species; 3) Note on Biloculina mud.* Ibid., new ser., vol. 21, pp. 31-71.

Species not figured, but neotypes have been selected by the British Museum (Natural History). *Bulimina williamsoniana; Miliolina transversestriata; Miliolina separans; Miliolina rupertiana; Miliolina incrassata; Hauerina circinata; Lagena favosopunctata; Lagena hertwigiana; Lagena schulzeana; Polystomella imperatrix; Polystomella verriculata.*

1884 – *Report on the foraminifera collected by H.M.S. "Challenger" during the years 1873-1876.* Challenger Exped. 1873-1876, Rept., Zool., vol. 9, pp. 1-184, pls. 1-115.

Biloculina ringens Lamarck var. *striolata; Spiroloculina convexiuscula; Miliolina crassatina; Cornuspira lacunosa; Textularia fugosa; Textularia crispata; Textularia transversaria; Bolivina nitida; Lagena spiralis; Lagena formosa* Schwager var. *brevis; Lagena quadrangularis; Polymorphina seguenzana; Sagrina limbata; Spirillina limbata* Brady var. *denticulata; Truncatulina tenuimargo; Rotalia papillosa; Rotalia papillosa* Brady var. *compresiuscula; Rotalia clathrata.*

BRADY, H. B., PARKER, W. K., AND JONES, T. R.

1870 – *A monograph of the genus Polymorphina.* Linnean Soc. London, Trans., vol. 27, pp. 197-253, pls. 39-42.

Polymorphina regina.

CARPENTER, W. B., PARKER, W. K., AND JONES, T. R.

1862 – *Introduction to the study of the foraminifera.* London: Ray Society, pp. 1-319, pls. 1-22.

Discorbina dimidiata, type, tfs. p. 201.

CHAPMAN, F.

1898 – *On Haddonia, a new genus of the foraminifera from Torres Strait.* Linnean Soc. London, Jour., Zool., vol. 26, pp. 452-456, pl. 28.

Haddonia; Haddonia torresiensis.

1904 – *On some foraminifera and Ostracoda from the Jurassic (lower Oolite) strata, near Geraldton, Western Australia.* Roy. Soc. Victoria, Proc., new ser., vol. 16, pt. 2, pp. 185-206, pls. 22-23.

Textularia crater; Bulimina gregorii; Vaginulina schloenbachi Reuss var. *interrupta; Cristellaria daintreei; Cristellaria costata* (Fichtel and Moll) var. *compressa; Cristellaria costata* (Fichtel and Moll) var. *seminuda.*

1904 – *On some Cainozoic foraminifera from Brown's Creek, Otway Coast.* Victoria, Geol. Survey, Rec., vol. 1, pt. 3, pp. 227-230, pl. 22.

Lituola simplex; Ammodiscus incertus (d'Orbigny) var. *macilenta; Cyclammina complanata; Cyclammina paupera.*

1907 – *Recent foraminifera of Victoria – Some littoral gatherings.* Quekett Micr. Club, Jour., pp. 117-146, pls. 9-10.

Clavulina parisiensis d'Orbigny var. *multicamerata; Spirillina denticulo-granulata; Lagena acuticostata* Reuss var. *ramulosa.*

1907 – *Tertiary foraminifera of Victoria, Australia: The Balcombian deposits of Port Phillip; Part I.* Linnean Soc. London, Jour., Zool., vol. 30, pp. 10-35, pls. 1-4.

Biloculina angusta; Bulimina elegantissima d'Orbigny var. *apiculata.*

1909 – *On some microzoa from the Wianamatta shales, New South Wales.* New South Wales, Geol. Survey, Rec., vol. 8, pt. 4, pp. 334-338, pl. 54.

Nubecularia nitida; Discorbina cymbaloporoides; Pulvinulina insignis.

1910 – *A study of the Batesford limestone.* Roy. Soc. Victoria, Proc., new ser., vol. 22, pt. 2, pp. 263-314, pls. 52-55.

Verneuilina ensiformis; Pulvinulina scabricula; Polytrema minutum; Gypsina howchini.

1913 – *Description of new and rare fossils obtained by deep boring in the Mallee; Part I – Plantae; and Rhizopoda to Brachiopoda.* Ibid., new ser., vol. 26, pt. 1, pp. 165-191, pls. 14-19.

Ammodiscus ovalis; Frondicularia lorifera; Polystomella striatopunctata (Fichtel and Moll) var. *evoluta.*

1915 – *Report on the foraminifera and Ostracoda obtained by the F.I.S. "Endeavour" from the east coast of Tasmania and off Cape Wiles, South Australia.* Australia, Dept. Trade and Customs, Fisheries, Zool. (Biol.) Results . . . "Endeavour" 1909-1914, vol. 3, pt. 1, pp. 3-51, pls. 1-3.

Spiroloculina dorsata Reuss var. *circularis; Spiroloculina grata* Terquem var. *reticosa; Cornuspira carinata* (Costa) var. *expansa.*

1916 – *On some smaller fossils from the red limestone of Grange Burn near Hamilton, with a note on a new species.* Victorian Naturalist, vol. 32, no. 10, pp. 144-146, tf.

Bolivina hentyana.

1917 – *Monograph of the foraminifera and Ostracoda of the Gingin Chalk.* Western Australia, Geol. Survey, Bull., no. 72, pp. 1-81, pls. 1-14.

Massilina ginginensis; Sagraina maitlandiana; Sagraina monile; Bigenerina compressiuscula.

1918 – *Devonian foraminifera: Tamworth District, New South Wales.* Linnean Soc. New South Wales, Proc., vol. 43, pt. 2, pp. 385-394, pls. 39-42.

Psammosphaera neminghensis; Valvulina oblonga; Pulvinulina bensoni.

1922 – *Report on an examination of material obtained from a bore at Torquay.* Victoria, Geol. Survey, Rec., vol. 4, pt. 2, pp. 315-324, pl. 3.

Spiroloculina torquayensis; Carpenteria proteiformis Goës var. *plecte.*

1922 – *Sherbornina: A new genus of foraminifera from Table Cape, Tasmania.* Linnean Soc. London, Jour., Zool., vol. 34, pp. 501-503, pl. 32.

Sherbornina; Sherbornina atkinsoni.

1923 – *Report on fossils from an Upper Cambrian horizon at Loyola, near Mansfield.* In: Howitt, A. W., *Phosphate deposits in the Mansfield District; Appendix I.* Victoria, Geol. Survey, Bull., no. 46, pp. 34-45, pls. 11-13.

Reophax antiquorum.

1926 – *Geological notes on Neumerella, and the section from Bairnsdale to Orbost.* Roy. Soc. Victoria, Proc., new ser., vol. 38, pp. 125-142, pl. 10.

Jaculella neumerellensis.

1927 – *On a limestone containing Lepidocyclina and other foraminifera from the Cape Range, Exmouth Gulf, W. A.* Ibid., new ser., vol. 39, pt. 2, pp. 125-148, pl. 12.

Bolivina spiroplectiformis.

1933 – *Some Palaeozoic fossils from Victoria.* Ibid., new ser., vol. 45, pt. 2, pp. 245-248, pl. 11.

Hemigordius lilydalensis; Trochammina bursaria.

1941 – *Report on foraminiferal soundings and dredgings of the F.I.S. "Endeavour" along the continental shelf of the south-east coast of Australia.* Roy. Soc. South Australia, Trans., vol. 65, pt. 2, pp. 145-211, pls. 7-9.

Planularia australis; Lagenonodosaria scalaris (Batsch) var. *seminuda; Bulimina notovata; Bolivinita quadrilatera* (Schwager) var. *tortilis; Parafrondicularia helenae; Notorotalia decurrens; Chilostomella cushmani; Sigmoilina latissima.*

Chapman, F., and Crespin, I.

1928 – In: Chapman, F., *The Sorrento bore, Mornington Peninsula, with a description of new or little-known fossils.* Victoria, Geol. Survey, Rec., vol. 5, pt. 1, pp. 1-195, pls. 1-11.

Spiroloculina dispansa; Frondicularia nuda; Truncatulina mundula Brady, Parker and Jones var. *carinata.*

1930 – *Rare foraminifera from deep borings in the Victorian Tertiaries – Victoriella, gen. nov., Cycloclypeus communis Martin, and Lepidocyclina borneënsis Provale.* Roy. Soc. Victoria, Proc., new ser., vol. 42, pt. 2, pp. 110-114, pls. 7-8.

Victoriella.

1930 – *Rare foraminifera from deep borings in the Victorian Tertiaries; Part II.* Ibid., new ser., vol. 43, pt. 1, pp. 96-100, pl. 5.

Cyclammina rotundata; Cyclammina longicompressa; Lingulina bartrumi Chapman var. *metungensis; Vaginulina gippslandica; Carpenteria rotaliformis; Carpenteria alternata; Lamarckina glencoensis.*

1932 – *Rare foraminifera from deep borings; Part III.* Ibid., new ser., vol. 44, pt. 1, pp. 92-99, pls. 11-13.

Lepidocyclina (Nephrolepidina) howchini; Lepidocyclina (Nephrolepidina) hamiltonensis.

Chapman, F., and Howchin, W.

1905 – *A monograph of the foraminifera of the Permo-Carboniferous limestones of New South Wales.* New South Wales, Geol. Survey, Mem., Pal., no. 14, pp. 1-22.

Haplophragmium pokolbiense; Pelosina hemisphaerica; Placopsilina tenuitesta; Lituola cristellarioides; Stacheia simulans; Monogenerina pyramidis; Pleurostomella? antiqua; Geinitzina triangularis; Anomalina supracarbonica.

CHAPMAN, F., HOWCHIN, W., AND PARR, W. J.

1934 – *A revision of the nomenclature of the Permian foraminifera of New South Wales.* Roy. Soc. Victoria, Proc., new ser., vol. 47, pt. 1, pp. 175-189, tfs.

Lingulina davidi; Ammodiscus planoconvexus.

CHAPMAN, F., AND PARR, W. J.

1926 – *Tertiary foraminifera of Victoria, Australia: The Balcombian deposits of Port Phillip; Part II.* Linnean Soc. London, Jour., Zool., vol. 36, pp. 373-399, pls. 17-21.

Uvigerina pygmaea d'Orbigny var. *macilenta.*

1931 – *Notes on new and aberrant types of foraminifera.* Roy. Soc. Victoria, Proc., new ser., vol. 43, pt. 2, pp. 236-238, pl. 9.

Hofkerina; Heronallenia.

1935 – *Foraminifera from soundings made by the trawler "Bonthorpe" in the Great Australian Bight.* Roy. Soc. Western Australia, Jour., vol. 21, pp. 1-6, pl. 1.

Pyrgo fornasinii; Clavulina serventyi.

1937 – *On the discovery of fusulinid foraminifera in the Upper Palaeozoic of North-West Australia, with a note on a new bivalve.* Victorian Naturalist, vol. 53, pp. 175-179, pl. 16.

Verbeekina sp.; *Neoschwagerina* sp.

1938 – *Australian and New Zealand species of the foraminiferal genera Operculina and Operculinella.* Roy. Soc. Victoria, Proc., new ser. vol. 50, pt. 2, pp. 279-299, pls. 16-17.

Operculina victoriensis.

CHAPMAN, F., PARR, W. J., AND COLLINS, A. C.

1934 – *Tertiary foraminifera of Victoria, Australia: The Balcombian deposits of Port Phillip; Part III.* Linnean Soc. London, Jour., Zool., vol. 38, no. 262, pp. 553-577, pls. 8-11.

Discorbis bertheloti (d'Orbigny) var. *papillata; Discorbis balcombensis; Discorbis tuberculata* (Balkwill and Wright) var. *australiensis; Pulvinulinella? tenuimarginata; Rotalia howchini; Globorotalia dehiscens; Cibicides victoriensis.*

COLLINS, A. C.

1953 – *Pleistocene foraminifera from Port Fairy, western Victoria.* Melbourne, Nat. Mus. Victoria, Mem., no. 18, pp. 93-105, pl. 1.

Quinqueloculina moynensis; Fabularia lata; Planispirinella tenuis; Buliminella gracilis.

CRESPIN, IRENE

1941 – *The genus Cycloclypeus in Victoria.* Roy. Soc. Victoria, Proc., new ser., vol. 53, pt. 2, pp. 301-314, pls. 12-15.

Cycloclypeus victoriensis; Cycloclypeus victoriensis var. *gippslandica.*

1943 – *The genus Lepidocyclina in Victoria.* Ibid., new ser., vol. 55, pt. 2, pp. 157-180, pls. 3-9.

Lepidocyclina (Trybliolepidina) batesfordensis; Lepidocyclina (Trybliolepidina) gippslandica.

1944 – *Some Lower Cretaceous foraminifera from bores in the Great Artesian Basin, northern New South Wales.* Roy. Soc. New South Wales, Jour., vol. 78, pp. 17-24, pl. 1.

Haplophragmoides chapmani; Trochammina raggatti; Trochammina parvula; Spiroplectammina cushmani; Marginulina subcretacea; Lenticulina warregoensis; Lenticulina gunderbookaensis; Planulina cretacea.

1945 – *Some Permian foraminifera from eastern Australia.* Roy. Soc. Queensland, Proc., vol. 56, pt. 3, pp. 23-30, pl. 3.

Nodosaria springsurensis; Nodosaria serocoldensis; Dentalina grayi; Frondicularia parri.

1950 – *Some Tertiary foraminifera from Victoria, Australia.* Cushman Found. Foram. Res., Contr., vol. 1, pt. 3-4, pp. 70-75, pl. 10.

Bathysiphon angleseaensis; Ammodiscus parri; Quinqueloculina singletoni; Quinqueloculina ornithopetra; Frondicularia victoriae; Dimorphina janjukensis.

1952 – *Two new species of Lepidocyclina from Cape Range, northwestern Australia.* Ibid., vol. 3, pt. 1, pp. 28-32, pls. 6-8.

Lepidocyclina (Eulepidina) badjirraensis; Lepidocyclina (Eulepidina) manduensis.

1953 – *Lower Cretaceous foraminifera from the Great Artesian Basin, Australia.* Ibid., vol. 4, pt. 1, pp. 26-36, pls. 5-6.

Pelosina lagenoides; Haplophragmoides dickinsoni; Ammobaculites fischeri; Ammobaculites minimus; Spiroplectammina edgelli; Ammobaculoides coonanensis; Ammobaculoides pitmani; Ammobaculoides romaensis; Textularia anacooraensis; Verneuilina howchini; Bigenerina loeblichae; Trochammina minuta; Lenticulina australiensis; Marginulina marreensis; Pseudoglandulina regularis; Lagena apiculata Reuss var. *phialaeformis; Valvulineria infracretacea; Anomalina mawsoni.*

CRESPIN, IRENE, AND PARR, W. J.

1940 – *Arenaceous foraminifera from the Permian rocks of New South Wales.* Roy. Soc. New South Wales, Jour., vol. 64, pp. 300-311, pls. 12-13.

Ammodiscus multicinctus; Ammobaculites woolnoughi; Trochammina pulvillus; Digitina; Digitina recurvata.

CUSHMAN, J. A.

1927 – *Some new genera of the foraminifera.* Cushman Lab. Foram. Res., Contr., vol. 2, pt. 4, pp. 77-81.

Tubulogenerina; Tubulogenerina mooraboolensis.

1927 – *Foraminifera of the genus Siphonina and related genera.* U. S. Nat. Mus., Proc., vol. 72, no. 2716, pp. 1-15, pls. 1-4.

Siphonina australis; Siphoninoides laevigata (Howchin) redescribed and figured; *Siphoninoides echinata* (Brady) redescribed and figured.

1929 – *The genus Bolivinella and its species.* Cushman Lab. Foram. Res., Contr., vol. 5, pt. 2, pp. 28-34, pl. 5.

Bolivinella folia (Parker and Jones) var. *ornata; Bolivinella australis.*

1933 – *An illustrated key to the genera of foraminifera.* Cushman Lab. Foram. Res., Spec. Publ., no. 5, pls. 1-40.

Tubulogenerina mooraboolensis Cushman and *Trillina howchini* Schlumberger refigured.

1936 – *New genera and species of the families Verneuilinidae and Valvulinidae and of the subfamily Virgulininae.* Ibid., no. 6, pp. 1-70, pls. 1-7.

Gaudryina collinsi; Gaudryina (Siphogaudryina) victoriana; Gaudryina (Pseudogaudryina) crespinae; Gaudryina (Pseudogaudryina) parri; Clavulinoides parri; Clavulinoides szaboi (Hantken) var. *victoriensis; Dorothia parri; Goesella parri; Goesella chapmani; Verneuilina parri; Listerella victoriensis; Listerella howchini; Bolivina hebes* Macfadyen var. *victoriensis, Bolivina sublobata; Bolivina victoriana; Bolivina crespinae.*

1936 – *Some new species of Nonion.* Cushman Lab. Foram. Res., Contr., vol. 12, pt. 3, pp. 63-69, pl. 12.

Nonion victoriense.

1936 – *Some new species of Elphidium and related genera.* Ibid., vol. 12, pt. 4, pp. 78-91, pls. 14-15.

Elphidium howchini; Elphidium crespinae; Elphidium chapmani; Elphidium crassatum (given in plate explanation as *Elphidium victoriense*); *Elphidium parri; Elphidium pseudoinflatum; Elphidium pseudonodosum* (given in plate explanation as *Elphidium australe*); *Elphidium papillosum; Elphidium subinflatum; Elphidium hispidulum; Elphidium sculpturatum; Polystomellina australis; Polystomellina miocenica.*

1937 – *A monograph of the foraminiferal family Valvulinidae.* Cushman Lab. Foram. Res., Spec. Publ., no. 8, pp. 1-210, pls. 1-24.

The following species are redescribed and figured: *Clavulina multicamerata* Chapman; *Cribrobulimina polystoma* (Parker and Jones); *Dorothia parri* Cushman; *Goesella chapmani* Cushman; *Listerella howchini* Cushman; *Listerella victoriensis* Cushman.

1937 – *A monograph of the subfamily Virgulininae of the foraminiferal family Buliminidae.* Ibid., no. 9, pp. 1-228, pls. 1-24.

The following species are redescribed and figured: *Bolivina hebes* Macfadyen var. *victoriensis* Cushman; *Bolivina victoriana* Cushman; *Bolivina crespinae* Cushman; *Rectobolivina bifrons* (Brady) var. *sydneyensis* (Goddard and Jensen); *Tubulogenerina mooraboolensis* Cushman.

1937 – *A monograph of the foraminiferal family Verneuilinidae.* Ibid., no. 7, pp. 1-157, pls. 1-20.

The following species are redescribed and figured: *Verneuilina parri* Cushman; *Gaudryina collinsi* Cushman; *Gaudryina (Siphogaudryina) victoriana* Cushman; *Gaudryina (Pseudogaudryina) crespinae* Cushman; *Gaudryina (Pseudogaudryina) parri* Cushman; *Gaudryina (Pseudogaudryina) hastata* Parr; *Clavulinoides parri* Cushman; *Clavulinoides szaboi* (Hantken) var. *victoriensis* Cushman.

1939 – *A monograph of the foraminiferal family Nonionidae.* U. S. Geol. Survey, Prof. Papers, no. 191, pp. 1-176, pls. 1-20.

The following species are redescribed and figured: *Nonion victoriense* Cushman; *Astrononion australe* Cushman and Edwards; *Elphidium howchini* Cushman; *Elphidium crassatum* Cushman; *Elphidium chapmani* Cushman; *Elphidium crespinae* Cushman; *Elphidium evolutum* (Chapman); *Elphidium hispidulum* Cushman; *Elphidium macellum* (Fichtel and Moll) var. *limbatum* Chapman; *Elphidium parri* Cushman; *Elphidium pseudoinflatum* Cushman; *Elphidium pseudonodosum* Cushman; *Elphidium papillosum* Cushman; *Elphidium sculpturatum* Cushman; *Elphidium subinflatum* Cushman; *Polystomellina australis* Cushman; *Polystomellina miocenica* Cushman.

1944 – *The genus Articulina.* Cushman Lab. Foram. Res., Spec. Publ., no. 10, pp. 1-21, pls. 1-4.

Articulina crespinae; Articulina parri; Articulina victoriana.

1945 – *The species of the subfamily Reussellinae of the foraminiferal family Buliminidae.* Cushman Lab. Foram. Res., Contr., vol. 21, pt. 2, pp. 23-54, pls. 5-8.

The following species are redescribed and figured: *Reussella ensiformis* (Chapman); *Reussella decorata* (Heron-Allen and Earland); *Pavonina triformis* Parr.

1946 – *The genus Hauerina and its species.* Ibid., vol. 22, pt. 1, pp. 2-15, pls. 1-2.

Hauerina parri; Hauerina tateana (Howchin) redescribed and figured.

1946 – *The genus Sigmoilina and its species.* Ibid., vol. 22, pt. 2, pp. 29-45, pls. 5-8.

Sigmoilina chapmani; Sigmoilina sigmoidea (Brady) var. *compressa; Sigmoilina australis* (Parr) recorded and figured.

1946 – *Sigmoilina victoriensis Cushman, a new name.* Ibid., vol. 22, pt. 3, p. 103.

1946 – *The genus Ceratobulimina and its species.* Ibid., vol. 22, pt. 4, pp. 107-117, pls. 17-19.

The following species are redescribed and figured: *Ceratobulimina westraliensis* Parr; *Ceratobulimina dehiscens* (Heron-Allen and Earland); *Ceratobulimina (Ceratocancris) australis* Cushman and Harris.

CUSHMAN, J. A., AND EDWARDS, PATRICIA G.

1937 – *Astrononion, a new genus of the foraminifera, and its species.* Cushman Lab. Foram. Res., Contr., vol. 13, pt. 1, pp. 29-36, pl. 3.

Astrononion australe.

CUSHMAN, J. A., AND HARRIS, R. W.

1927 – *Some notes on the genus Ceratobulimina.* Cushman Lab. Foram. Res., Contr., vol. 3, pt. 4, pp. 171-177, pls. 29-30.

Ceratobulimina hauerii (d'Orbigny) var. *australis; Ceratobulimina dehiscens* (Heron-Allen and Earland) recorded and figured.

CUSHMAN, J. A., AND OZAWA, Y.

1930 – *A monograph of the foraminiferal family Polymorphinidae, Recent and fossil.* U. S. Nat. Mus., Proc., vol. 77, no. 2829, pp. 1-185, pls. 1-40.

Guttulina regina (Brady, Parker and Jones) var. *crassicostata; Guttulina (Sigmoidina) silvestrii; Pseudopolymorphina rutila* (Cushman) var. *parri; Polymorphina howchini; Sigmomorphina chapmani* (Heron-Allen and Earland) redescribed and figured.

CUSHMAN, J. A., AND PARKER, FRANCES L.

1937 – *Notes on some Oligocene species of Bulimina and Buliminella.* Cushman Lab. Foram. Res., Contr., vol. 13, pt. 1, pp. 36-40, pl. 4.

Buliminella apiculata (Chapman) var. *hebetata; Buliminella apiculata* recorded and figured.

1946 – *Bulimina and related foraminiferal genera.* U. S. Geol. Survey, Prof. Papers, no. 210-D, pp. 55-176, pls. 15-30.

Redescribed and figured: *Buliminella westraliensis* Parr; *Buliminella madagascariensis* (d'Orbigny) var. *spicata* Cushman and Parker; *Bulimina notovata* Chapman.

CUSHMAN, J. A., AND TODD, RUTH

1942 – *The genus Cancris and its species.* Cushman Lab. Foram. Res., Contr., vol. 18, pt. 4, pp. 72-94, pls. 17-24.

Cancris intermedius; Cancris ovatus.

1944 – *The genus Spiroloculina and its species.* Cushman Lab. Foram. Res., Spec. Publ., no. 11, pp. 1-82, pls. 2-9.

Recorded and figured: *Spiroloculina torquayensis* Chapman; *Spiroloculina dispansa* Chapman and Crespin.

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Frondicularia trimorpha; Nodosaria roemeri Neugeboren var. *semicostata; Reophax lodderae.*

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1924 – *The foraminifera of Lord Howe Island, South Pacific.* Linnean Soc. London, Jour., Zool., vol. 35, pp. 599-646, pls. 35-37.

Miliolina auberiana (d'Orbigny) var. *semireticulata; Craterites; Craterites rectus; Diffusilina; Diffusilina humilis; Bolivina limbata* Brady var. *abbreviata; Discorbina lauriei; Discorbina pyramidalis; Spirillina campanula.*

1924 – *The Miocene foraminifera of the "Filter Quarry," Moorabool River, Victoria, Australia.* Roy. Micr. Soc. London, Jour., pp. 121-186, pls. 7-14.

Nubecularia lucifuga Defrance var. *producta; Cornuspira obscura; Verneuilina decorata; Chrysalidina costata; Bigenerina ferox; Bulimina convoluta* Williamson var. *dehiscens; Lagena balaniformis; Lagena curvi-costata; Lagena orbignyana* Seguenza var. *bifida; Frondicularia compta; Frondicularia compta* var. *villosa; Frondicularia australis; Polymorphina chapmani; Uvigerina canariensis* d'Orbigny var. *australis; Discorbina margaritifera; Discorbina globigeriniformis; Discorbina inflata; Discorbina haliotis; Planorbulina larvata* Parker and Jones var. *inaequilateralis; Planorbulina plana; Pulvinulina scabra* Brady var. *umbilicata.*

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Hauerina intermedia; Spiroloculina tateana; Miliolina angularis; Discorbina cruciformis; Truncatulina echinata Brady var. *laevigata; Pulvinulina semiornata; Orbitoides stellata.*

1891 – *The foraminifera of the older Tertiary, Muddy Creek, Victoria – Addenda et Corrigenda.* Ibid., vol. 14, pt. 2, pp. 355-356, pl. 13.

Rhabdogonium exsculptum.

1891 – *The foraminifera of the older Tertiary (No. 2, Kent Town Bore, Adelaide).* Ibid., vol. 14, pt. 2, pp. 350-354, pl. 13.

Truncatulina margaritifera (Brady) var. *adelaidensis.*

1894 – *On the occurrence of foraminifera in the Permo-Carboniferous rocks of Tasmania.* Australasian Assoc. Adv. Sci., Rept., 5th Meeting (Adelaide, 1893), pp. 344-348, pls. 10-11.

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1895 – *Carboniferous foraminifera of Western Australia, with descriptions of new species.* Roy. Soc. South Australia, Trans., vol. 19, pp. 194-200, pl. 10.

Cornuspira schlumbergeri; Nodosaria irwinensis; Frondicularia woodwardi.

1895 – *Two new species of Cretaceous foraminifera.* Ibid., vol. 19, p. 200, pl. 10.

Patellina jonesi; Haplophragmium australis.

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1938 – *Notes on the geological features and foraminiferal fauna of the Metropolitan Abbatoirs Bore, Adelaide.* Ibid., vol. 62, pt. 2, pp. 287-317, pls. 15-19.

Quinqueloculina adelaidensis; Spiroloculina lapidigera; Nodobaculariella cultrata; Elphidium rotatum; Elphidium adelaidense; Discorbis cycloclypeus; Sigmomorphina subregularis; Operculina? umbonifera; Rotalia verriculata.

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1904 – *Contributions to a knowledge of Australian foraminifera.* Linnean Soc. New South Wales, Proc., vol. 29, pt. 4, pp. 810-831, pl. 23.

Reophax euneta; Polymorphina alveoliniformis; Polystomella hedleyi.

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1870 – *Australian Mesozoic geology and palaeontology.* Geol. Soc. London, Quart. Jour., vol. 26, pp. 226-261.

Cristellaria cultrata (Montfort) var. *radiata; Cristellaria acutauricularis* (Fichtel and Moll) var. *longistriata.*

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1931 – *A new species of the foraminifera, Cassidulinoides chapmani.* Victorian Naturalist, vol. 48, no. 5, pp. 99-100, tf.

1932 – *Victorian and South Australian shallow-water foraminifera; Part I.* Roy. Soc. Victoria, Proc., new ser., vol. 44, pt. 1, pp. 1-14, pl. 1.

Proteonina spiculifera; Reophax friabilis; Quinqueloculina australis; Quinqueloculina ammophila; Bolivina subreticulata.

1932 – *Victorian and South Australian shallow-water foraminifera; Part II.* Ibid., new ser., vol. 44, pt. 2, pp. 218-234, pls. 21-22.

Gaudryina hastata; Vaginulina vertebralis; Reussia armata; Discorbis australis; Discorbis vesicularis (Parker and Jones) var. *acervulinoides; Discorbis collinsi; Anomalina nonionoides.*

1933 – *Notes on Australian and New Zealand foraminifera; No. 2 – The genus Pavonina and its relationships.* Ibid., new ser., vol. 45, pt. 1, pp. 28-31, pl. 7.

Pavonina triformis.

1938 – *Upper Eocene foraminifera from deep borings in King's Park, Perth, Western Australia.* Roy. Soc. Western Australia, Jour., vol. 24, pp. 69-101, pls. 1-3.

Pseudoglandulina clarkei; Lagena luciae; Lagena perthensis; Lagena terrilli; Vaginulina subplumoides; Buliminella westraliensis; Angulogerina subangularis; Bolivinopsis crespinae; Gümbelina venezuelana Nuttall var. *rugosa; Heronallenia pusilla; Ceratobulimina westraliensis; Pulvinulinella obtusa* (Burrows and Holland) var. *westraliensis; Anomalina perthensis; Anomalina westraliensis; Cibicides pseudoconvexus; Cibicides umbonifer; Globorotalia chapmani.*

1939 – *Foraminifera of the Pliocene of south-eastern Australia.* Mining and Geol. Jour., vol. 1, no. 4, pp. 65-70, pl. 1.

Pseudopolymorphina victoriensis; Glandulina kalimnensis; Siphonodosaria australis; Rotalia hamiltonensis; Planulina kalimnensis.

1941 – *A new genus Planulinoides, and some species of foraminifera from southern Australia.* Ibid., vol. 2, no. 5, p. 305, tf.

1941 – *Foraminifera and a tubicolous worm from the Permian of the North-West Division of Western Australia.* Roy. Soc. Western Australia, Jour., vol. 27, pp. 97-115, pls. 1-2.

Ammodiscus nitidus; Ammodiscus wandageensis; Hyperammina coleyi; Hyperamminoides acicula; Tolypammina undulata; Glomospira adhaerens; Psammosphaera pusilla; Crithionina teicherti; Reophax subasper; Reophax tricameratus; Trochammina subobtusa.

1942 – *New genera of foraminifera from the Tertiary of Victoria.* Mining and Geol. Jour., vol. 2, no. 6, pp. 361-363, tfs. 1-5.

Crespinella; Austrotrillina.

1945 – *Recent foraminifera from Barwon Heads, Victoria.* Roy. Soc. Victoria, Proc., new ser., vol. 56, pt. 2, pp. 189-218, pls. 7-12.

Webbina bassensis; Quinqueloculina subpolygona; Quinqueloculina baragwanathi; Triloculina bassensis; Vaginulina bassensis; Lagena distoma-margaritifera Parker and Jones var. *victoriensis; Fissurina subquadrata; Fissurina contusa; Rectobolivina digitata; Discorbis kennedyi; Elphidium argenteum.*

1946 – *Post-Tertiary foraminifera from a bore near Rosebud, Victoria.* Melbourne, Nat. Mus. Victoria, Mem., no. 14, pt. 2, pp. 123-128, tfs. a-b.

Bolivina rugosa.

1947 – *The lagenid foraminifera and their relationships.* Roy. Soc. Victoria, Proc., new ser., vol. 58, pts. 1-2, pp. 116-130, pls. 6-7.

1947 – *An Australian record of the foraminiferal genus Hantkenina.* Ibid., new ser., vol. 58, pts. 1-2, pp. 45-47, tfs. 1-6.

Hantkenina alabamensis Cushman subsp. *compressa.*

1950 – *Foraminifera.* B.A.N.Z. Antarctic Res. Exped. 1929-1931, Rept., ser. B, vol. 5, pt. 6, pp. 233-392, pls. 3-15, tfs. 1-8.

Textularia australis; Botellina tasmanica; Psammophax tasmanica; Reophax brevis; Reophax pseudodistans Cushman var. *tenuis; Cyclammina tasmanica; Siphotextularia obesa; Trochammina appressa; Trochammina spiculolega; Trochammina gaboensis; Trochammina sorosa; Trochammina tasmanica; Eggerella subconica; Dorothia pusilla; Cornuspira tasmanica; Spiroloculina subimpressa; Spiroloculina sublimbata; Spiroloculina angusteoralis, Sigmoilina sabulosa; Triloculina striatula; Triloculina lamellidens; Pyrgo subglobulus; Oolina tasmanica; Fissurina bassensis; Fissurina quinqueannulata; Fissurina collinsi; Fissurina subcircularis; Fissurina bimarginata; Fissurina aperturo-alata; Fissurina basifimbriata; Fissurina pacifica; Parafissurina basicarinata; Parafissurina biannulata; Parafissurina quadrata; Parafissurina scaphaeformis; Parafissurina subcircularis; Parafissurina subalata; Parafissurina tasmanica; Parafissurina tricarinata; Lenticulina subgibba; Lenticulina (Robulus) tasmanica; Lenticulina (Robulus) suborbicularis; Lenticulina (Robulus) australis; Lenticulina (Robulus) altifrons; Vaginulinopsis tasmanica; Vaginulinopsis procelata; Marginulina perobesa; Vaginulina rheophagica; Amphicoryne scalaris* (Batsch) var. *compacta; Dentalina translucens; Dentalina subemaciata; Frondicularia bassensis; Siphoglobulina siphonifera; Buliminella basicostata; Bulimina submarginata; Virgulina rotundata; Bolivina bassensis; Uvigerina bassensis; Ehrenbergina pacifica* Cushman var. *aspinosa; Spirillina pectimarginata* Chapman, Parr and Collins var. *aspinosa; Spirillina multispira; Turrispirillina depressa; Discorbis umbonifer; Discorbis lobatulus; Heronallenia laevis; Heronallenia parva; Ceratobuliminoides bassensis; Valvulineria polita; Valvulineria porifera; Eponides pusillus; Mississippina pacifica; Anomalina tasmanica; Anomalina bassensis; Dyocibicides laevis; Robertina tasmanica.*

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1930 – *Notes on Australian and New Zealand foraminifera; No. 1 – The species of Patellina and Patel-*

linella, with a description of a new genus Annulopatellina. Roy. Soc. Victoria, Proc., new ser., vol. 43, pt. 1, pp. 89-95, pl. 4.

Patellina annectens; Annulopatellina.

1937 – *Notes on Australian and New Zealand foraminifera; No. 3 – Some species of the family Polymorphinidae.* Ibid., new ser., vol. 50, pt. 1, pp. 190-211, pls. 12-15.

Guttulina regina (Parker and Jones) var. *chapplei; Guttulina clifdenensis; Pyrulina crespinae; Pseudopolymorphina doanei* (Galloway and Wissler) var. *beaumarisensis; Pseudopolymorphina tasmanica; Polymorphina myrae; Sigmomorphina haeusleri; Sigmomorphina wynyardensis; Sigmomorphina batesfordensis; Sigmoidella novozealandica.*

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1891 – *Description of a new species of Fabularia.* Roy. Soc. South Australia, Trans., vol. 14, pt. 2, pp. 346-349, tfs. 1-4, pl. 13.

Fabularia howchini.

1893 – *Note sur les genres Trillina et Linderina.* Soc. Géol. France, Bull., ser. 3, vol. 21, no. 2, pp. 119-120, tf. 1, pl. 3.

Trillina howchini.

SIDEBOTTOM, H.

1918 – *Report on the Recent foraminifera dredged off the east coast of Australia.* Roy. Micr. Soc. London, Jour., pp. 1-25, pls. 1-2; pp. 121-153, pls. 3-5; pp. 249-264, pl. 6.

Frondicularia pacifica; Vaginulina rheophagica; Dimorphina milletti; Uvigerina porrecta Brady var. *fimbriata; Discorbina bertheloti* (d'Orbigny) var. *complanata; Discorbina circularis; Discorbina tuberculata* Balkwill and Wright var. *acuta; Discorbina involuta; Discorbina lingulata* Burrows and Holland var. *unguiculata; Anomalina sinuosa.*

SECTION B

Publications in which lists of and references to Australian foraminifera are given:

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1943 – *Eocene deposits south-east of Princetown, Victoria, with appendix on foraminifera by M. F. Glaessner and W. J. Parr.* Roy. Soc. Victoria, Proc., new ser., vol. 55, pt. 2, pp. 234-254.

1944 – *The geology of Port Campbell District.* Ibid., new ser., vol. 56, pt. 1, pp. 77-108.

1950 – *Geology and physiography of the Moonlight Head District, Victoria.* Ibid., new ser., vol. 60, pp. 17-42.

1953 – *The relationship of Cyclammina-bearing sediments to the older Tertiary deposits south-east of Princetown, Victoria.* Melbourne, Nat. Mus. Victoria, Mem., no. 18, pp. 125-134.

BANNINK, D. D.

1948 – *Een monografie van het genus Operculina d'Orbigny, 1826.* (Leiden, Univ., doct. diss.) Leiden: the author, pp. 1-159, pls. 1-19.

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1937 – *Boring for oil, Lakes Entrance.* Victoria, Geol. Survey, Rec., vol. 5, pt. 4, pp. 561-566.

1937 – *Oil in Gippsland.* Ibid., vol. 5, pt. 4, pp. 644-645.

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1951 – *Underground water survey of portion of the Murray Basin (Counties Albert and Alfred).* South Australia, Geol. Survey, Bull., vol. 25.

BOUTAKOFF, N., AND SPRIGG, R. S.

1953 – *Summary report on the petroleum possibilities of the Mt. Gambier Sunklands.* Mining and Geol. Jour., vol. 5, no. 2, pp. 28-37.

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1910 – *The Irwin River coalfield and the adjacent districts from Arrino to Northampton.* Western Australia, Geol. Survey, Bull., vol. 38, pp. 1-108.

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1850 – *Structure of Nummulina, Orbitolites and Orbitoides.* Geol. Soc. London, Quart. Jour., vol. 6, pp. 21-38, pls. 3-8.

1856 – *Researches on the foraminifera; Part II – On the genera Orbiculina, Alveolina, Cycloclypeus and Heterostegina.* Roy. Soc. London, Philos. Trans., vol. 146, pp. 547-569, pls. 28-31.

1883 – *Report on specimens of the genus Orbitolites collected by H.M.S. "Challenger" during 1873-1876.* Challenger Exped. 1873-1876, Rept., Zool., vol. 7, pp. 1-47, pls. 1-8.

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1902 – *Recent foraminifera – Shoreham District.* Victorian Naturalist, vol. 19, no. 8, p. 112.

1903 – *Note on the occurrence of pelagic foraminifera, Cymbalopora (Tretomphalus) bulloides, on the coast of South Australia.* Ibid., vol. 19, no. 11, pp. 153-154.

1905 – *Notes on the older Tertiary foraminiferal rocks on the west coast of Santo, New Hebrides.* Linnean Soc. New South Wales, Proc., vol. 30, pt. 2, pp. 261-274, pls. 5-8.

1907 – *Notes on fossils from the Collie coalfield, Western Australia, in the collection of the National Museum, Melbourne.* Western Australia, Geol. Survey, Bull., no. 27, pp. 9-18, pl. 2.

1908 – *A sketch of the life history of the foraminifera.* Victorian Naturalist, vol. 25, no. 8, pp. 123-124.

1908 – *On dimorphism in the Recent foraminifer, Alveolina boscii Defr. sp.* Roy. Micr. Soc. London, Jour., pp. 151-153, pls. 2-3.

1910 – *Victorian foraminifera – Recent and fossil.* Victorian Naturalist, vol. 26, no. 12, pp. 190-195.

1912 – *Notes on a collection of Tertiary limestones and their fossil contents from King Island.* Melbourne, Nat. Mus. Victoria, Mem., no. 4, pp. 29-53.

1912 – *Report on a sample of Globigerina ooze from 112 fathoms, east of Tasmania.* Australia, Dept. Trade and Customs, Fisheries, Zool. Results . . . "Endeavour" 1909-1910, vol. 3, pp. 309-311, pl. 3.

1913 – *Victorian fossiliferous limestones and their correlatives in other lands.* Victorian Naturalist, vol. 30, no. 8, pp. 139-141.

1914 – *Descriptions of new and rare fossils obtained in the Mallee; Part III – Ostracoda to fishes, with a complete list of fossils found in the borings.* Roy. Soc. Victoria, Proc., new ser., vol. 27, pt. 1, pp. 28-71, pls. 6-10.

1914 – *On the succession and homotaxial relationships of the Australian Cainozoic system.* Melbourne, Nat. Mus. Victoria, Mem., no. 5, pp. 5-52.

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1915 – *On the age and sequence of the Tertiary strata of south-eastern Australia.* Brit. Assoc. Adv. Sci., Rept., 84th Meeting (Australia, 1914), pp. 371-372.

1915 – *Report on a collection of fossils made by Dr. A. Wade from the Cainozoic series of South Australia; Appendix II.* In: *Supposed oil-bearing areas of South Australia.* South Australia, Geol. Survey, Bull., vol. 4, pp. 44-50.

1915 – *Notes on foraminifera and Ostracoda found in a sample of sand at Williamstown Beach.* Victorian Naturalist, vol. 32, no. 3, pp. 49-52, tfs.

1916 – *Cainozoic geology of the Mallee and other Victorian bores.* Victoria, Geol. Survey, Rec., vol. 3, pt. 4, pp. 327-411, pls. 63-68.

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1920 – *Notes on a collection of Tertiary fossils from Ooldea and Watson, South Australia.* Roy. Soc. Victoria, Proc., new ser., vol. 32, pt. 2, pp. 225-245, pls. 16-17.

1921 – *Fossils and oil discovery.* Australian Business, vol. 1, no. 7, pp. 13-15.

1921 – *Foraminifera – Presidential Address.* Micr. Soc. Victoria, Proc., vol. 3, no. 10, pp. 40-41.

1922 – *The geology of the Mallee.* Victorian Naturalist, vol. 37, no. 11, pp. 124-127.

1923 – *The fossiliferous beds of Violet Creek, near Hamilton.* Ibid., vol. 40, no. 8, pp. 148-151.

1924 – *Microscopy in oil finding.* Micr. Soc. Victoria, Proc., vol. 3, no. 42, pp. 169-171.

1925 – *The classification and shell structure of the foraminifera.* Ibid., vol. 4, no. 5, pp. 20-23.

1925 – *Foraminifera and oil; Valuable aid to research; How data should be collected.* Melbourne *Argus*, September 19, 1925, 2 figs.

1925 – *Tertiary fossils from bore cores, Port Fairy.* Victoria, Geol. Survey, Rec., vol. 4, pt. 4, pp. 481-483.

1926 – *Cretaceous and Tertiary foraminifera of New Zealand, with an appendix on the Ostracoda.* New Zealand, Geol. Survey, Pal. Bull., no. 11, pp. 1-119.

1926 – *On age and content of limestone specimens from the Negri series, Kimberley Division.* Western Australia, Geol. Survey, Bull., no. 88, pp. 34-35.

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1931 – *The occurrence of some British and Australian foraminifera in Cambrian rocks.* (Title only.) Ibid., p. 192.

1933 – *Note on glauconite grits and cherts of Cretaceous age associated with Nullagine series of Western Australia.* (Abstract.) Australian and New Zealand Assoc. Adv. Sci., Rept., 21st Meeting (Sydney, 1932), p. 87.

1933 – *Note on our present knowledge of the Permian foraminifera of Western Australia.* Ibid., pp. 453-454.

1934 – *The foraminifera, their collection, preparation and identification.* Micr. Soc. Victoria, Proc., vol. 6, no. 20, pp. 76-79.

1934 – *Book of fossils.* Sydney: Shakespeare Head.

1935 – *Note on the correlation of the Carboniferous and Permian formations of Australia.* Australian and New Zealand Assoc. Adv. Sci., Rept., 22nd Meeting (Melbourne), p. 460.

1936 – *Fifty years in micropalaeontological work.* Micr. Soc. Victoria, Proc., vol. 6, no. 45, pp. 188-191.

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notes and comment

Pelagic foraminifera in the Thanet beds, and the use of Thanetian as a stage name

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During a revision of the microfauna of the Thanet beds of eastern Kent in the United Kingdom, *Globigerina pseudobulloides* Plummer and *Globigerina triloculinoides* Plummer were recovered from the sandy silts exposed in the cliffs at Reculver, together with specimens very near *Globorotalia velascoensis* (Cushman) var. *acuta* Toulmin. The former two species occur also in the upper Paleocene of Sweden (Brotzen, 1948). These species have been shown to be of great stratigraphic value elsewhere. In his latest work on Tertiary pelagic foraminifera, Grimsdale (1951) suggests that the joint occurrence of these forms is indicative of an upper Paleocene age, both in the Middle East "Thanetian" of Iraq, Syria, Palestine and Egypt, and in the American upper Midway of the Gulf Coast and Caribbean areas.

The discovery of these forms in the Thanet beds, in addition to emphasising the upper Paleocene age of the formation, adds weight to the observations of Stainforth (1950) and Grimsdale (1951) on the value of pelagic foraminifera in inter-regional correlation. The rarity of these pelagic species may support the concept of the Northwest-European basin of deposition as having been almost isolated (ten Dam, 1944). Their occurrence, however, shows that open-sea connections must have existed, possibly to the northward if the southwest passage was closed (Stamp, 1921, and Wills, 1951) between the Northwest-European basin and the Gulf Coast area in lower Landenian time.

The stage name Landenian is used here in the sense of Stamp (1921), who recognised the Thanet beds and the Woolwich and Reading beds as deposits of the same sedimentary cycle. The term Thanetian as used by French authors includes the "Sables de Bracheux" and is generally equivalent to Landenian, as is Thanetian as used by Grimsdale in the Middle East. Brotzen, in contrast, uses both Thanetian and Landenian. In this sense, Thanetian is equivalent to the time period represented by the Thanet formation only. To avoid confusion, the term Thanetian should be either restricted in this manner or dropped, and the Thanet beds, being regarded as deposited in the first half of the Landenian cycle, should be referred to the lower Landenian substage (lower upper Paleocene).

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Dissection of highly perforate calcareous foraminifera

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The writer has recently been engaged in an investigation of the internal structures of certain Orbulinas and has experienced considerable difficulties in preserving the very fragile inner structures of these highly perforate foraminifera whilst removing part of the outer chamber by the use of dilute acid. A recent article entitled "Foram surgery," by Troelsen (1954, Micropaleontologist, vol. 8, no. 4, pp. 40-41) prompts the writer to add some further comments on the technique of using acid to dissolve away outer walls.

In working with Globigerinas and Orbulinas, the problem of the preservation of internal structures is intensified because of the large pores. If hydrochloric acid is used, the acid floods all parts of the test, mainly by capillary attraction through the pores, with consequent destruction of the fragile internal walls and partitions. This flooding occurs even before the outer chambers are broken through.

Independently, the writer realised the problem was one concerning the viscosity of the acid used, and a number of trial and error experiments led him, at first, to adopt a method very similar to the one described by Troelsen. However, some disadvantages were found in merely adding acid to gum. These were mainly concerned with the rapid drying of the gum/acid mixture at the high temperatures prevalent whilst working under the microscope lamp. As the mixture dried, the foraminifera were often picked up and torn away from their mounting, adhering to the tip of the brush in a most exasperating manner, with dire results to both specimens and temper. Consequently, since unfilled specimens are not plentiful, it has been necessary for me to develop a less destructive method. The salient points of this method are as follows.

Firstly, the specimen is lightly smeared all over with gum arabic, in preference to gum tragacanth, then mounted with as little gum as possible, since it was found that the "opened" specimen undergoes cracking and eventual disintegration as excess gum continues to dehydrate. When the coating of gum is sufficiently hardened, applications of dilute acid are made, using a slightly damp brush of the finest possible calibre. It has been found that if a gentle circular motion is used, a gradual reduction of the wall thickness can be achieved in such a manner as to avoid a collapse of the outer walls before it is possible to make sure that no internal structures will be damaged by continued action. In this connection, it is useful to note that a mixture of gum arabic and HCl seems to have useful refractive properties which enable the worker to see through the reduced wall whilst working.

An additional advantage in this method is that, should a large quantity of acid be inadvertently transferred to the specimen, the coating of gum prevents chemical reaction for a sufficient time for the worker to take appropriate neutralizing action. As the wall is completely removed, the small flakes of undissolved wall do not fall into the interior, where they are difficult to remove, but are pulled back to the unaffected part of the test by the surface tension of the gum arabic-HCl mixture.

The writer would like to point out that it is essential to wash the specimen in a dilute alkaline solution when the work is completed, since it was found that, after leaving the work for a few days, further chemical action had continued slowly, with dire results. Finally, to remove the surplus gum, washing in 30% alcohol has been found to be very effective, especially if a few drops of methylene blue are added to the alcohol. This makes details more visible in reflected light.

Jean Le Calvez (1908-1954)

JEAN LE CALVEZ

Le décès brutal et inattendu de Jean Le Calvez, le 4 Août 1954, a causé une grande perte pour tous les biologistes et également pour les micropaléontologistes.

Jean Le Calvez né le 27 Juillet 1908 à Jouy (Eure et Loir — France) se destinait á l'enseignement primaire. Il fit ses études à l'École Normale d'Instituteurs de Chartres. Plus tard, attiré par les sciences naturelles et plus particulièrement la zoologie, il poursuivit ses études en vue de la Licence, qu'il obtint en 1931. Dès 1933, il était nommé préparateur à la Station de Zoologie Marine de Villefrance s/Mer (Alpes Maritimes), puis, en 1934, Assistant de Zoologie au Laboratoire de Biologie Marine de Banyuls-sur-Mer (Pyrénées Orientales).

C'est pendant son séjour à ces deux laboratoires, qu'il put commencer ses travaux sur la biologie des foraminifères, en particulier sur la reproduction de ces protistes. Il étudie les gamètes des foraminifères (1935) et apporte une importante contribution à l'étude du problème des modifications du test des foraminifères pélagiques *Orbulina universa* et *Tretomphalus bulloides*, en rapport avec la reproduction.

De quatre années consacrées presque exclusivement à l'étude de la biologie des foraminifères devait résulter, en 1938, la publication de la Thèse de Doctorat, ouvrage fondamental pour la connaissance des processus de développement et de reproduction des foraminifères. Dans ce travail fondamental, Le Calvez a montré la place, dans le cycle évolutif, des formes microsphériques B et macrosphériques A ainsi que des formes A_1 et A_2 définies par Hofker. Il a montré l'alternance, chez certaines espèces, au cours d'un cycle complet de reproduction, des formes A et B, ainsi que, dans certains cas, des formes A_1, A_2 et B. Il a pu établir sur des bases biologiques que le "trimorphisme" (purement morphologique) d'Hofker était loin d'avoir la généralité que celui-ci lui attribuait.

Nommé Chef de Travaux au Laboratoire de Banyuls, Le Calvez poursuit ses recherches de biologie pure, qui l'amènent à approfondir les modalités de la reproduction chez d'autres groupes animaux que les foraminifères.

Ces études sont interrompues pendant la guerre 1939-1945, que Jean Le Calvez accomplit comme Lieutenant. Sa brillante conduite lui mérite une citation à l'ordre du Régiment, la Croix de Guerre avec étoile de bronze, et la croix des services militaires volontaires. Après la captivité, Le Calvez reprend son activité scientifique.

Il est nommé Maître de conférences à la Faculté des Sciences de Bordeaux en 1942, puis de Rennes en 1944. Dès 1946, les publications diffusent des découvertes dans le domaine très spécialisé de la biologie nucléaire et chromosomique, chez les drosophiles, les amphipodes et d'autres petits groupes. Citons enfin son importante participation au chapitre des foraminifères dans le Traité de Zoologie publié sous la direction du professeur Grasse. En 1950, il est nommé Professeur à la Faculté des Sciences ainsi qu'à l'École de Médecine et de Pharmacie de Rennes.

La liste complète de ses publications, si elle est relativement courte, 40 titres de 1934 à 1953, reflète bien le caractère méticuleux de Le Calvez, qui apportait à son travail une minutie et un soin exemplaire. Il a préféré publier peu, mais ne rien laisser au hasard. On peut être certain de trouver sous la signature de Le Calvez le résultat d'un travail poursuivi avec le seul souci de la recherche de la vérité. Il avait, en sa femme, Yolande Le Calvez, une collaboratrice de premier plan, dont les publications micropaléontologiques font autorité. À une conscience et une probité scientifique élevées, il joignait une cordialité d'accueil que n'oublieront pas ceux qui l'ont fréquenté, et prodiguait sans compter ses conseils aux débutants.

LISTE CHRONOLOGIQUE DES PUBLICATIONS DE JEAN LE CALVEZ

1934 – *Embryons à cinq loges de Planorbulina mediterranensis (d'Orb.) et trimorphisme de cette espèce.* Soc. Zool. France, Bull., vol. 59, pp. 284-290.

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news reports

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RUDOLF GRILL

Micropaleontology and geology suffered a heavy loss in the death of Rudolf Noth, who passed away in Vienna on December 11, 1954. He was a remarkable man, perhaps one of the greatest authorities on the numerous oil-producing areas between the Caucasus and the Atlantic. Through long, close association, he knew well the people and languages of the various countries where these deposits occur. Noth's graduate work dealt with the foraminifera of the Carpathian Flysch. His paper was entitled "Die Foraminiferen der roten Tone von Barwinek und Komarnok in Galizien," and was published in the Beiträge zur Geologie und Paläontologie Österreich-Ungarns (vol. 25, Vienna, 1912).

It is a noteworthy fact that at the suggestion of his great teacher, Victor Uhlig, Noth undertook in 1910 one of the earliest, if not the first core description involving an analysis of its microfauna for the purpose of determining the age of the rocks penetrated. This was no easy task, since the well (Frankstadt, Moravia) first penetrated Cretaceous Flysch sandstones, which were overthrust upon Tertiary beds underlain by Carboniferous rocks. Unfortunately, Noth's description of the Frankstadt well was never published. It was deposited in the files of the Mines Department of Czechoslovakia.

Noth kept pace with all progress and changes in working methods up to his last publication (1954, in collaboration with G. Woletz), which deals, as did his first, with the microfauna of the Cretaceous Flysch. A more complete report on his life and work will appear shortly in the Verhandlungen der Geologischen Bundesanstalt for 1955, Number 2.

Noth's last work deals with the Kaumberger beds (Flysch) of the northeastern Alps, which have hitherto been considered to be Lower Cretaceous. In addition to arenaceous foraminifera (*Ammodiscus, Glomospira, Trochamminoides, Recurvoides,* etc.), he found *Globotruncana lapparenti coronata* Bolli, which indicates a post-Cenomanian age for this unit. The overlying sandy slates contain *Rzehakina epigona* (Rzehak), and are therefore considered to be uppermost Cretaceous or lowermost Eocene. *Rzehakina* has been encountered in the upper Campanian at Gosau, south of Vienna, in the Helveticum near Nussbach, Upper Austria, together with *Globotruncana,* and also north of Vienna in variegated shales that contain arenaceous forms and grade into Nummulite-bearing beds. All of these deposits are therefore considered to be Paleocene.

The explanatory text for the geologic map of Vienna was issued during 1954. It stresses the importance of micropaleontology in the present stage of research work. The microfaunas typical of the Flysch and Helveticum were reported upon by R. Noth, those of the Miocene (Tortonian and Sarmatian) by R. Grill, and the ostracodes of the Pliocene by K. Turnovsky. Each of these reports is illustrated by excellent plates. The stratigraphy as a whole is summarized in four tables, which form an up-to-date review of our present understanding of the Triassic, Jurassic, Cretaceous and Tertiary. The publication is the result of teamwork by G. Götzinger, R. Grill, H. Küpper, E. Lichtenberger, and G. Rosenberg, and was edited by R. Grill and H. Küpper.

The Gänserndorf sheet (1:75,000) of the geologic map of Austria, whose explanation was written by R. Grill, also demonstrates the degree to which the stratigraphy of these Tertiary areas depends upon micropaleontology.

Those in attendance at the meeting of the Paläontologische Gesellschaft, held in Vienna in August, 1954, visited and collected at many of the localities in the Vienna Basin. Some of the papers presented also dealt with micropaleontology.

A. Papp has published a study of the development of *Pseudorbitoides* and *Lepidorbitoides* in Europe. He summarizes in a table all data that are considered to be important in the subdivision of the Senonian as based on

orbitoids. Morphogenetic studies on *Heterostegina* have been published by A. Papp and K. Küpper in the Contributions from the Cushman Foundation. E. Kamptner has reported on the fine structure of the coccoliths. W. Klaus is continuing his palynological work with the Geologische Bundesanstalt. He has published reports on Alpine salt-rock sequences and on the detailed stratigraphy of the brown coal (younger Tertiary) of western Styria, and has submitted for publication a morphographic study of a new type of pollen from Upper Austria (Hausruck).

Recent publications

GRILL, R., AND KÜPPER, H.
1954 – *Erläuterungen zur geologischen Karte der Umgebung von Wien.* Vienna: Geol. Bundesanst., 138 pp., 15 pls., 4 tables.

KAMPTNER, E.
1954 – *Untersuchungen über den Feinbau der Coccolithen.* Arch. Protistenk., vol. 100, pp. 1-90, 50 tfs.

KLAUS, W.
1954 – *Braunkohlen-Palynologie einiger weststeirischer Lagerstätten (Vorläufiger Bericht).* Austria, Geol. Bundesanst., Verh., pp. 170-179, tfs. 1-2, 1 table.

1954 – *Alpine Salz-Sporendiagnose.* Zeitschr. Deutsch. Geol. Ges., Jahrg. 1953, pp. 234-236.

[MS.] *Bau und Form von Sporotrapoidites illingensis n. gen. et sp. sporomorpharum.* Botaniska Notiser, Lund.

NOTH, R., AND WOLETZ, G.
1954 – *Zur Altersfrage der Kaumberger Schichten.* Austria, Geol. Bundesanst., Verh., pp. 143-151, 1 table.

PAPP, A.
1954 – *Über die Entwicklung von Pseudorbitoides und Lepidorbitoides in Europa.* Austria, Geol. Bundesanst., Verh., pp. 162-170, 1 tf., 1 table.

PAPP, A., AND KÜPPER, K.
1953 – *Über Stolonen und Auxiliarkammern bei Orbitoides und Lepidorbitoides.* Österr. Akad. Wiss., Math.-Naturw. Kl., Sitzber., vol. 162, pp. 273-277, 1 pl.

1954 – *The genus Heterostegina in the Upper Tertiary of Europe.* Cushman Found. Foram. Res., Contr., vol. 5, pt. 3, pp. 108-127, pls. 20-23, 52 tfs., tables 1-2.

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HEINRICH HILTERMANN

Germany micropaleontology has suffered a great loss in the passing away of the algologist and palynologist Hermann Budde, who was born November 24, 1890, and died July 18, 1954. Aside from his professional activities as an assistant master at Dortmund, he carried on his work without any help from a scientific institution. A few years ago, he received a professorship at the Botanical Institute of the University of Münster. Special credit is due Professor Budde for his activities in broadening our knowledge of calcareous fresh-water algae, diatoms, and pollen. In addition to textbooks and popular literature, he published some twenty papers on these three specialized groups.

The meeting of the Paläontologische Gesellschaft in Vienna, August 23-26, 1954, was a great success in every respect. We are much indebted to our Austrian colleagues for the invitation and for the extremely cordial reception we had. Some of the papers included in the extensive program are especially interesting to micropaleontologists. E. Voigt (Hamburg) spoke on the occurrence of serpulids in bryozoan zooecia; R. Potonié (Krefeld) on the biology of Carboniferous spores and on the sporologic results of the Eighth International Congress of Botanists in Paris; W. Gross (Berlin) on the problem of the conodonts; F. Schmid (Hannover) on the paleontologic definition of stages and substages in the Upper Cretaceous; A. Papp (Vienna) on morphogenetic and genetic investigations on foraminifera; W. J. Schmidt (Vienna) on the stratigraphic value of the Serpulidae in the Tertiary; W. Hagn (Munich) on the taxonomy and nomenclature of Alpine Eocene foraminifera; and E. Kamptner (Vienna) on the present state of our knowledge of the calcareous flagellates.

At the invitation of the Laboratoire de Micropaléontologie of the Institut Français du Pétrole, ten German micropaleontologists, together with colleagues from other Central European countries, were given an opportunity to visit important type localities in France and to obtain samples. We should like to express here our most sincere gratitude to our French colleagues, who organized this meeting in such an excellent manner. Our thanks were also expressed by H. Bartenstein in a note in Erdöl und Kohle (vol. 8, p. 100).

During 1954, three of the so-called "Austauschsitzungen für Mikropaläontologie und Stratigraphie" (meetings for the exchange of ideas in micropaleontology and stratigraphy) were held in Germany. They were as follows:

Meeting 75: March 4, 1954. Held at the Geological and Paleontological Institute of the University of Göttingen, at the invitation of Professor H. Schmidt. Professor Schmidt's candidates for the doctor's degree reported on the following subjects: J. C. Pratsch on the Malm in southern Portugal; Gernot Schmid on microfaunas and stratigraphy of the middle Malm in the mountainous districts of Lower Saxony. Hermann Schmidt led a field trip to the Levin clay pit, the type locality of Bornemann's Lias foraminifera.

Meeting 76: April 29, 1954. Held at the Gewerkschaft Brigitta in Steimbke, district of Nienburg/Weser. W. Klinger spoke on microfaunal and stratigraphic studies of the Kimmeridgian and Portlandian in the area between the Weser and Aller Rivers.

Meeting 77: May 25-26, 1954. K. Sauer spoke on the stratigraphy of the Swabian Lias and Dogger, E. Buck spoke on the microstratigraphy of the Lias and Dogger in the Wutach

River area, and both conducted a field trip through the complete Lias and Dogger profile from Aselfinger to Achdorf and Eschach.

Recent publications

BARTENSTEIN, H.
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1954 – *Derzeitiger Stand der Mikropaläontologischen Arbeitstechnik in Deutschland.* Pal. Zeitschr., vol. 28, pp. 208-212, pls. 18-19.

1955 – *Mitteleuropäische Mikropaläontologen-Tagung Paris, 18. bis 23. September 1954.* Erdöl und Kohle, Hamburg, vol. 8, p. 100.

BARTENSTEIN, H., AND HEINEMANN, W.
1954 – *Brackwasser - Foraminiferen im oberen Aquitan des Mittelrhein-Gebietes.* Senckenbergiana lethaea, vol. 35, pp. 23-35, 3 tfs.

BECKMANN, H.
1954 – *Zur Kenntnis der fossilen Spirorben.* Senckenbergiana lethaea, vol. 35, pp. 107-113, 1 pl., 3 tfs.

BHARDWAJ, D. C.
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ITALY

ENRICO DI NAPOLI ALLIATA

Micropaleontological activities in Italy during 1954 were almost exclusively concerned with the study of Tertiary and Recent foraminifera, although there were a few papers published on ostracodes.

Geological Institute of Milan

A sample of mud obtained by Professor Picard in his bathyscaphe from a depth of 1300 meters in the Tyrrhenian Sea was studied by Mrs. M. B. Cita. Pelagic assemblages predominate. Quantitative analyses of planktonic and benthonic forms are given, along with comparisons with other Recent Mediterranean foraminiferal faunas. Illustrations of foraminiferal assemblages are presented.

Mrs. Cita has also listed foraminifera collected in the Varese area from the "Molasse" formation, whose age has been under discussion. The new faunal study indicates that the age is Oligocene. The environment is believed to have been deep water, because of the occurrence of arenaceous and pelagic forms. These foraminiferal faunas are related to those of Central America rather than to those of Europe.

Miss E. Consonni has studied small Tertiary outcrops in the Brianza area in connection with her thesis. They consist of sandy marls with alternating conglomerates. Some foraminifera were found in the marly beds, which indicate an age range of upper Oligocene to lower Miocene. Some horizons with arenaceous foraminifera (*Bathysiphon*, etc.) are also present. A few species are illustrated in Miss Consonni's thesis, none of which are new.

A study of a stratigraphic section extending from the Oligocene to the Pliocene in the type area of the Tortonian (northern Apennines, near Tortona) has been published. This study was carried out by Dr. G. Gino, who made the geologic map of the area; Dr. E. di Napoli, who studied the Oligocene sequence; Miss M. A. Ruscelli, who studied the Helvetian stage; and Dr. A. Gianotti, who studied the Tortonian and Sarmatian stages. The Oligocene sequence is represented by greenish marly clays which contain rich foraminiferal faunas. In all, 102 species and varieties were identified. Two of the species are new, *Pleurostomella rameroensis* and *Ellipsopleurostomella oligocenica*. Planktonic individuals predominate. Among the benthonic forms, the Ellipsoidinidae, Buliminidae, Lagenidae and Rotaliidae predominate in number of species. The environment is off-shore marine bathyal. The age is defined as upper Oligocene. Comparison was made with other Italian, European and non-European Tertiary microfaunas. This comparison showed that affinities with the European faunas are not very close. On the contrary, a remarkable affinity is noted especially with microfaunas of lower middle Oligocene age in the Cipero marl of Trinidad, and in general with the Central American belt including Santo Domingo, Cuba, Puerto Rico, Panama, Mexico, and Venezuela. The most important forms found in the Oligocene sequence of Tortona are illustrated.

The Helvetian of the same area is represented by gray marl and sand, which lies unconformably upon the Oligocene beds. Yellowish sandstones follow above. In all, 173 species and varieties were identified, two of which are new. They are *Heronallenia desioi* and *Cibicides mexicanus* var. *miocenicus*. The study points out two different sedimentary environments to which different faunal assemblages correspond. The greatest faunal analogies are with coeval faunas of the northern Apennines. Range charts showing the distribution of the microfossils in various samples are included in this paper.

The Tortonian and Sarmatian samples were collected in the Rio Mazzapiedi section, where Mayer established the Tortonian stage. The lithologic sequence consists of three different units, a lower gray marly clay directly overlying the Helvetian sandstone, a calcareous sandstone, and an upper marly clay. The series ends above with a brown shale and gypsum formation. About 400 species and varieties were identified, four of which are new. They are *Chrysalidinella ruscellii*, *Tritubulogenerina dertonensis*, *Bitu-*

bulogenerina dertonensis, and *Ehrenbergina pacifica Cushman var. basispinosa.*

The relationship between faunal assemblages and lithologic units is discussed. Faunal variations in relation to lithologic and bathymetric changes, as well as to changes in salinity and temperature, throughout the whole section, are also discussed. An assemblage of very large arenaceous foraminifera, together with *Robulus* and *Nodosaria,* was noted in connection with sandstones, whereas clays and marly beds contained abundant *Lagena,* Globigerinidae, and *Pyrgo.* The influence of temperature increase upward was indicated by the appearance of abundant *Globigerinoides ruber, Globigerinoides sacculifer* and *Orbulina universa,* and, among the benthonic forms, by the appearance of *Cushmanella, Chrysalidinella, Buliminella,* and *Tretomphalus,* which are now widespread in the warm waters of the Pacific area. The explosive increase in the number of species observed in the upper clay beds, which grade into the gypsum formation, was probably related to increasing salinity. Further increase in the salinity in the brown clays immediately underlying the gypsum resulted in a decrease in the number of species and specimens, and produced a peculiar assemblage of large *Orbulina universa, Bulimina echinata,* and *Uvigerina tenuistriata,* which show a degenerative tendency in coiling and strong development of ornamental features. The gypsum formation itself is barren.

With regard to the age, it is to be noted that in the upper part of the section (upper marly clay) numerous species appear that are generally widespread in Pliocene beds. The number of extinct species decreases rapidly. The fauna of this interval shows more affinity with Pliocene faunas than with those of the lower part of the Tortonian section. The brown marl below the gypsum, containing degenerate faunas, may be considered Sarmatian.

Geological Institute of Turin

Dr. C. Socin has noted and listed foraminifera ranging in age from middle Eocene to Pliocene in the Turin and Monferrato areas.

Geological Institute of Padua

Dr. F. Ferasin and F. Protodecima list foraminifera ranging in age from Upper Cretaceous to upper Eocene, from the "Colli Euganei" area (Veneto).

Geological Institute of Ferrara

Dr. B. Accordi has noted marine foraminiferal faunas with prevalent *Nonion commune,* found in Pleistocene outcrops in the Bolognese Apennines. This discovery is of particular interest, since chert artifacts of lower Paleolithic age have also been found in the same beds with the foraminifera. Relationships between marine faunas and glacial phases are discussed.

Geological Institute of Rome

Dr. G. Negretti has studied a Nummulitic limestone outcropping near Colleferro (Rome). He found that this limestone contains, along with middle Eocene *Nummulites* and *Discocyclina,* various species of *Lepidocyclina* of Miocene type. On this basis the age was established as Miocene. The *Nummulites* and associated forms are considered to be reworked in transgressive beds of the lower Miocene.

Servizio Geologico d'Italia, Rome

Professor T. Lipparini has reported on microfaunal assemblages found in the northern Apennines near Bologna, which range in age from Cretaceous to Pliocene. The same author has reported on the stratigraphic sequence in the Termini Imerese area (Palermo). In that area, limestones with *Orbitoides* and *Siderolites* are overlain by red marls with *Globotruncana,* which grade into Nummulitic limestone and marl with *Globorotalia,* of Paleocene age. Varicolored clays and marls with larger foraminifera follow, ranging in age from lower Eocene to lower Miocene.

Geological Institute of Naples

Mrs. Z. M. Moncharmont has studied a foraminiferal fauna from blue clays outcropping at Cutrofiano, near Lecce. The presence of *Anomalina balthica* and *Anomalina turgida* leads her to postulate a marine environment with cold water. The age is considered to be lower Calabrian. The faunal assemblage is illustrated.

Institute of Applied Geology, Naples

A list of foraminifera, with predominantly arenaceous forms and a few Globotruncanas, ranging in age from Cretaceous to Oligocene, identified by Miss A. Spada, is given in a paper by Professor Ippolito on applied geology in the lower Agri Valley (Lower Apennine-Basilicata).

Geological Laboratory of AGIP, Lodi

Dr. V. Conato, of the micropaleontological staff of AGIP, has reported the occurrence in Italy of *Globigerinita naparimaensis,* ranging from the lower to the upper Pliocene. This genus, which was first found in Trinidad, is also widely distributed in Italy.

Dr. B. Martinis, of the geological staff of AGIP, has completed paleontological work on the Pliocene of the Piedmont, where there are several Pliocene type localities. Seven stratigraphic sections have been studied, and numerous samples collected. The Pliocene is represented by blue clays (Piacenzian facies), which grade upward into yellow sands (Astian facies), sandstones and calcarenites. The study was extended to the Po Valley, where AGIP drilled three holes as a part of its oil and gas research program. These holes, which attained a depth of 2900 meters, penetrated the entire Pliocene sequence. They were stopped when upper Miocene beds were reached. Abundant foraminiferal faunas were collected, studied and listed. A range chart showing the distribution of the microfaunas in various samples is included in Dr. Martinis' paper. The Pliocene is subdivided into upper, middle and lower stages, and the typical foraminiferal assemblages are given.

The environmental conditions from the lower Pliocene upward grade from marine lower neritic to shallow-water and lagoonal. The geologic history and paleogeography of the Piedmont are given. In all, 231 species and varieties have been identified. Assemblages, and some of the more important species, are illustrated. The following new species and varieties are described and illustrated: *Lagenonodosaria scalaris* var. *cunensis, Robertina conatoi,* and *Bolivina villavernensis.*

Dr. E. Perconig, of the geological staff of AGIP, has studied microfaunas collected in the Ramaca area (Catania plain, Sicily). He lists foraminifera ranging in age from Langhian to Tortonian. A range chart showing comparison with the Po Valley faunas is given. The most common pelagic species are illustrated.

The same author has also studied foraminifera from blue clays outcropping near Agrigento, Sicily. Lists of foraminifera are presented, which indicate an upper Pliocene age. One new species, *Quinqueloculina padana,* is illustrated and described.

Centro Sperimentale per l'Industria Mineraria, Palermo

Miss E. Tamajo, of the micropaleontological laboratory attached to the "Centro Sperimentale," has studied microfaunas from samples collected near Caltanisetta, Sicily. The samples consist of clay with "brecciated texture," including fragments of various types of rocks. The study of these lithologic fragments indicates that they range in age from Cretaceous to Miocene. The matrix contains homogeneous, well-preserved microfaunas of Miocene to Pliocene age. It is noted that washing residues of such brecciated clays without considering the fact that various rock fragments are included may be misleading in interpreting the age and environment.

Dr. T. de Stefani has studied the foraminifera of Vallone Tre Pietre near Termini Imerese, Palermo. He shows the occurrence in this area of Cretaceous limestones with *Orbitoides,* which are unconformably overlain by the "Flysch" formation of Oligocene age. In this formation, Oligocene *Nummulites* and *Lepidocyclina* are associated with typical middle Eocene *Nummulites* and *Discocyclina,* which are considered to be reworked. This fauna was considered to be Eocene by older authors. The mixture of forms was taken as an example of the possible coexistence of Eocene and Oligocene foraminifera. Dr. de Stefani notes the occurrence of the Paleocene, which is represented by compact red marly limestone in northwestern Sicily. The fauna consists only of abundant species of *Globigerina* and *Gümbelina. Globotruncana* is absent.

Other news

Dr. C. Emiliani, who is now working at the Walker Museum in Chicago, has studied five foraminiferal faunas of probable lower Oligocene age collected in the northern Apennines, near Florence. Biometric data are given for each species when possible. The means and the coefficients of correlation and of variability are also calculated. Arenaceous specimens and species are frequent in all the samples. The environmental conditions are defined as tropical or subtropical waters of about 1200 meters depth. Ecologic data on temperature and depth were derived by comparison with assemblages living in the present-day oceans. Additional information was derived by observing the optima at which the families predominating in the five samples live today, and by studying Recent species and their present-day optima. A formula was applied in obtaining these ecologic data.

In all, 276 species and varieties were identified, 73 of which are new. Comparisons with other coeval faunas were made. The greatest similarities are with those of South America, California, eastern Mexico, and North Africa. A comparison chart showing chronological and geographic distribution indicates migration of foraminiferal faunas throughout the various areas during the time-period under consideration. For purposes of comparison, a "similarity index" was introduced. Five plates of photographs of foraminifera are presented.

Professor S. Venzo, who was recently appointed director of the Geological Institute of Parma, has studied the "Flysch" formation in the Bergamo and northern Brianza areas. A stratigraphic sequence about 3000 meters thick, extending from the Lower Cretaceous (Barremian) to the upper Eocene, was observed. Biostratigraphic units were established by means of ammonite and foraminiferal zones. The foraminifera were identified by Professor Selli, who lists some of the species. The stages of the Cretaceous were distinguished by means of species of *Globotruncana. Globotruncana (Thalmanninella) ticinensis* var. *alpha* appears for the first time in the lower Albian beds. The upper part of the Cretaceous contains *Orbitoides gensacicus, Lepidorbitoides socialis,* and *Orbitoides media.* Small foraminifera, among others *Globotruncana stuartii* and *Globotruncana contusa,* were also identified. The beds which directly overlie the above-mentioned faunas do not contain any *Globotruncana* or *Orbitoides,* but contain an assemblage composed exclusively of *Globigerina,* without *Globorotalia.* In Selli's opinion, this interval may represent the Danian stage. Predominantly larger foraminifera, such as *Nummulites* and *Discocyclina,* follow, ranging in age from lower to upper Eocene.

E. Bruschi, now a subsurface geologist with the American International Fuel and Petroleum Company in Sicily, has studied samples collected by Dr. Coggi in Piana dei Greci, in the Palermo area. He notes the presence of the Cenomanian and Turonian, represented by red marly limestone (Scaglia rossa), and the middle and upper Eocene, represented by marls and whitish marly limestones with a predominantly pelagic fauna. Yellowish gray breccias collected in the same area contain large foraminifera, among them *Nummulites fichteli* and *Lepidocyclina tournoueri,* which are characteristic of the Oligocene. General observations on the Oligocene of Sicily follow.

Together with Dr. Petrocchi, Mr. Bruschi has also studied a stratigraphic section near Terrasini, Palermo, rep-

resented by red limestone (Scaglia rossa) and marly white limestone. The foraminiferal sequences, with predominantly pelagic individuals, indicate continuous sedimentation from the Cenomanian to the middle upper Eocene. *Globotruncana* and *Globorotalia* species make it possible to distinguish the stages of the Cretaceous and Eocene.

Dr. E. di Napoli, micropaleontologist with the American International Fuel and Petroleum Company in Rome, has studied samples from a stratigraphic boring drilled many years ago near Palazzo Adriano, Palermo. The boring began in a Permian algal limestone, but after it had penetrated this formation for about 125 meters, marly clays were encountered with foraminifera clearly indicating a Tertiary age, ranging from Tortonian to Helvetian. This discovery makes it possible to determine the age of the tectonic movements involved in the overthrusting of the Permian limestone upon the Miocene clay. Some of the species and foraminiferal assemblages are illustrated.

Together with Dr. Malatesta, Dr. A. Torrente has studied foraminifera from a Tertiary sequence outcropping near Caltagirone, Sicily. This sequence begins at the base with a "white marl" (Trubi formation), followed above by blue and gray marls, overlain by yellowish coarse sands and sandstones. The age ranges from the lower Pliocene to the Calabrian, the latter containing some cold-water species. The transition beds from the Pliocene to the Calabrian are represented by brackish-water sediments. A range chart and illustrations of various foraminiferal assemblages are given.

Dr. Torrente also has reported on a foraminiferal fauna contained in core samples from a boring drilled in the Funtanazza area near Arcuento, northeastern Sardinia. The microfaunal assemblage indicates a middle lower Miocene age.

Dr. L. Ogniben, of the geological staff of Montecatini, has studied the gypsum beds in the Enna, Agrigento, and Caltanisetta areas, in connection with research on sulfur. Stratigraphic sequences were studied, and the occurrence of "brecciated clays," containing heterogeneous materials which he considers a result of submarine slumping, is noted. Several lists of foraminifera identified by Dr. di Napoli are given.

We think it useful also to record here some papers on the foraminifera of Italy written by foreign authors, which represent a very important contribution to the knowledge of Italian foraminifera. We refer especially to the following papers:

Dr. A. Bally has published a paper on Mount Majella (Abbruzzi), in which he describes several stratigraphic sections, ranging from Cretaceous to Tertiary, with biostratigraphic subdivisions made on the basis of the foraminifera. A range chart of large and small foraminifera is also included.

Dr. F. Schweighauser, in connection with his thesis, studied several stratigraphic sections ranging in age from Cretaceous to lower Oligocene, in the Veneto region, where classic Tertiary outcrops occur. The stratigraphic range and classification, chiefly of large foraminifera, are presented.

Dr. C. Drooger has studied *Miogypsina* from several localities in the Piedmont. Valuable biometric data are given, and a revision of the genus was undertaken.

Professor S. Conti has found a marly limestone referable to the Hettangian (lower Lias) in Val Solda, Lugano. It contains, along with typical megafossils, a number of ostracodes. In all, fourteen species and varieties have been identified, thirteen of which are new. They are: *Terquemia isoscela, Terquemia vanveeni, Terquemia hettangiana, Cytherelloidea valsoldensis, Cytherelloidea? lediformis, Bairdia postacutata, Bairdia desioi, Bairdia? proboscidata, Macrocypris lunganeensis, Macrocypris uniformis, Macrocypris mucronata, Macrocypris gigantea,* and *Cytheroidea ellipsoidea* Brady var. *reducta.*

During March, 1954, Dr. and Mrs. A. R. Loeblich, Jr., of the U. S. National Museum in Washington, visited Italy in order to collect samples from the most important foraminiferal localities. They visited all the Italian laboratories, and also went to Sicily and northern Italy.

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ENRICO DI NAPOLI ALLIATA
American International Fuel and Petroleum Company
Rome, Italy

TURKEY

A. SUAT ERK

Maden Tetkik ve Arama Enstitüsü (Mineral Research and Exploration Institute), Ankara

Formerly, all micropaleontological activities at the M.T.A. Enstitüsü were concentrated in the Paleontological Department of the Geology Division of the Institute. With increased drilling activity by the Institute's Petroleum Division, however, the need was felt for a Subsurface Department. Consequently, early in 1952, a Subsurface Department was established as part of the Petroleum Division, in accordance with a plan recommended by Dr. A. Suat Erk and Dr. A. ten Dam. Part of the personnel of the Micropaleontological Laboratory of the Institute was transferred to this new Department, which takes care of all applied micropaleontological work in connection with petroleum exploration by the Institute.

Mrs. Mehlika Taşman is in charge of the Subsurface Department. She is studying lithology, paleontology and facies in deep wells drilled in Thrace and in the Adana Basin. In that area, principally Neogene formations, and only occasionally some Mesozoic formations, are encountered.

A well-sample and core library has been established in the Department's storerooms, so that all samples and cores are readily available to geologists who wish to examine them. In addition, all written records on the exploration wells drilled by the Institute have been classified and placed in a well file. This system proved its usefulness when various oil companies started reconnaissance work in Turkey in 1953.

Mrs. Vecihe Öztemür and Mrs. Berrin Özbas are in charge of the routine micropaleontological study of all samples from wells drilled by the Petroleum Division in southeastern Turkey. Dr. Fritz Bender was formerly resident geologist in the Raman and Garzan areas of southeastern Turkey, and was in charge of the routine study of all samples from wells drilled in that area. He was also responsible for the geological supervision of the wells. He left the Subsurface Department in September, 1954, and is now with the Petroleum Geology Department of the Geology Division of the Institute, as a field geologist.

Mr. Fikret Kiraner is resident geologist for the Raman, Garzan, Kentalan, and Reşan areas of southeastern Turkey, and supervises all wells drilled in that area. He is in charge of the Raman field laboratory, which is equipped to handle sample washing, thin-sectioning of harder rocks, and calcimetric and fluoroscopic measurements. He accompanied Dr. ten Dam on a field trip through southeastern Turkey during the summer of 1954, sampling and measuring type sections of all formations exposed in that basin.

Dr. ten Dam is research geologist with the Subsurface Department, and has completed a detailed study of the lithology, stratigraphy, paleontology and facies of the Mesozoic in deep wells drilled in the foredeep basin of southeastern Turkey. Early in the summer of 1954, he started a study of the sedimentation, facies, stratigraphy and paleontology of that basin. Twenty type sections were measured and closely sampled during the field season of 1954. These samples will be studied in detail during the winter months.

Mr. Mehmet Taşdemiroğlu is in charge of the physicochemical laboratory of the Subsurface Department. He completed his training in 1953 at the École Nationale Supérieure du Pétrole at Rueil-Malmaison, France.

Dr. Erk is in charge of the Micropaleontological Laboratory of the geology Division of the Institute, and has just finished a report on the sedimentation, stratigraphy and paleontology of the Eocene, Paleocene and Mesozoic rocks north of Ankara. He has recently started a detailed micropaleontological study of the Jurassic-Cretaceous boundary in Turkey. In addition to his many administrative duties as Chief Paleontologist for M.T.A., he must also take care of micropaleontological work on field samples from Late Paleozoic rocks, as he is the Institute's specialist on Fusulinidae.

Mr. Cemal Öztemür, micropaleontologist, is continuing his study of the larger foraminifera of the Eogene and Neogene of eastern Turkey, and has nearly completed this voluminous work, which will be published in the near future. In addition to this research project, part of his time is devoted to routine determination of field samples, as he is the Institute's specialist on orbitoids and discocyclines.

Dr. R. Oberhauser, micropaleontologist with M.T.A. on an F.O.A. grant, is in charge of micropaleontological work on field samples from the Mesozoic of Turkey. He is preparing short papers on Jurassic larger foraminifera from Turkey, and on some forms from the Cretaceous of Turkey that are related to the genus *Trocholina*.

Dr. K. Turnovsky, also a micropaleontologist with M.T.A. on an F.O.A. grant, is in charge of micropaleontological work on field samples from the Cenozoic of Turkey. He is preparing a short paper on the Mio-Pliocene Ostracoda of western Turkey.

Mr. Süleyman Gez and Mr. Yunus Pekmen, associate micropaleontologists, have sampled and measured a detailed type section in the Eocene, Paleocene, and Upper Cretaceous southwest of Ankara, and have begun the micropaleontological study of these samples. Mr. Pekmen works principally on the Camerinidae, and handles most of the Institute's samples containing those forms.

Miss Sevinç Basat, associate micropaleontologist, is studying the microfaunas of the Jurassic of central Anatolia. Mrs. Utarit Bilgütay, microphytopaleontologist, is studying the microfloras, principally algae, in rocks of various ages from Turkey. Apart from detailed determinations of specially collected fossil material, many field samples containing algae are brought to her for routine age determinations. She is planning a trip to the United States in the near future to visit Dr. Harlan Johnson at the Colorado School of Mines.

Distinguished visitors to the Institute's installations in recent times were Dr. Louise Jordan of Tallahassee, Florida, and Dr. Paul Arni of Cairo, Egypt.

Ankara University, Faculty of Science

Dr. Erk is in charge of lectures on micropaleontology, and has begun organizing a micropaleontological laboratory at Ankara University. No research work by the students has been started there as yet.

Istanbul University, Faculty of Science

Mrs. Atife Dizer is in charge of lectures on micropaleontology. She has specialized for many years in the Camerinidae, and M.T.A. field samples are now being sent to her for determination. She recently qualified as a teacher with a study on the Nummulites of the Kastamonu Basin.

A. Suat Erk
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